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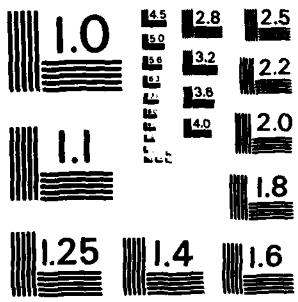

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HUMAN FACTORS ENGINEERING

A Self-Paced Text
Lessons 21-25

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HUMAN FACTORS ENGINEERING

A SELF-PACED TEXT

LESSONS 21-25

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PACIFIC MISSILE TEST CENTER

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HUMAN FACTORS ENGINEERING

Lesson 21

LESSON 21: SYSTEMS ACQUISITION

Present

Well, we're glad that you decided to experience the second half of this course. We hope it is a sign that, like I. M. Eager, you have gained an awareness and appreciation of the overall human factors engineering process. While I. M. suffered through the trauma of designing his super helicopter, we were able to sit back and profit by his experiences.

It is good to see that, like our hero, you have decided to learn more. Eager felt that he was lucky to have enrolled in Professor Ed U. Kator's applied HFE course, and we bet that you decided long ago that you needed to learn just how all the HFE puzzle pieces fit together. For the remainder of this course, ~~you will be studying~~ the big picture of systems acquisition as well as the specific contributions made by the HFE community to the acquisition process. Enough of the preliminaries. Let's go on into the classroom where Professor Kator is about to start his introductory lecture concerning systems acquisition. Figure 21.1 in your supplement will be useful to you during the course of the lesson. Figure 21.1 goes beyond the practical questions ~~that~~ a HFE specialist might ask.

The varied routes and myriad details of how the Federal government goes about procuring material is a complex subject that is well beyond the scope of our course. Department of Defense acquisition activities may include anything from direct procurement of corn flakes packaged to stay crisp in the tropics, to the development of major weapons systems, such as missiles, warships, and planes, and each potential acquisition of military system, equipment, and facilities may be subjected to the human engineering requirements of the Military Specification MIL-H-46855.

The human engineer is fundamentally concerned with making sure that the best possible designs are provided within the constraints of time, money, and technical capability. Cost weighs especially heavy in the system acquisition process. While less expensive systems may satisfy less stringent specifications and controls over the acquisition process, this is not always the case with HFE requirements. While some very expensive items may naturally meet stated HFE criteria, some relatively low unit cost items (such as back-pack carrying frames now in Army use) may require intensive human engineering efforts. Thus, the level of human factors input to systems acquisition is not determined by the cost of the system alone, but by the extent to which the system needs to be human engineered.

(Go on to the next page)

From Page 1

Well, what should you have concluded about systems acquisition so far?

(1) The only time that DOD is concerned with testing and evaluating products and systems is when they are new and unique to military application. Turn to Page 98.
(2) Existing military standards provide checklists to follow for all aspects of system acquisition. Turn to Page 92.
(3) There is no single uniform method to be followed in the DOD acquisition process. Turn to Page 70.

From Page 8

(4) Look a little more closely. Two of these answers are close and one is way out of line. Remember, we're looking for the instance in which the use of systems analysis is 'most important.' Return to Page 8.

From Page 84

(2) This is a true statement, but not the answer to our question. What makes this whole scheme a process and not a static event? Return to Page 84.

From Page 5

(3) You're only thinking of the small picture. This is only one example of a factor which can influence performance. Think big!! Return to Page 5.

From Page 48

(1) Your answer is incorrect. This might be an operational performance requirement, but is it the best or only performance requirement? Return to Page 48.

From Page 18

(3) Sorry, but this is a subtask of the system, not a function. Try another answer on Page 18.

From Page 85

(1) Right on, ol' buddy, this is the only example given which is a task a crewperson could perform. Orbiting earth and flying at supersonic speeds are functions required to achieve the overall mission of 'fly to the moon' or 'maintain interstellar peace.' Very good. Keep up the good work.

The tasks which you have identified should have three characteristics. Each should:

(1) Relate directly to a mission.
(2) Be required for that mission.
(3) Be stated in terms which are measurable.

For example, the last answer may more correctly be stated: 'using the available data, the operator must plot the flight path with X degree of error.' The plotting of a flight path is directly related to the mission, and is certainly required of the mission. Think about it for a moment. If you had to determine whether or not a math student had passed the math course, wouldn't you be specifying performance standards? Sure you would. Similarly, if you had to decide whether or not the infantry team had accomplished its mission, you would have some criteria to use in making that decision. Now, the question is what aspects of performance would you measure to develop those criteria? There are two attributes of performance which are typically used to measure human performance. Which two are they?

(1) User acceptability and accuracy. Turn to Page 33.
(2) Number of errors and type of error made. Turn to Page 80.
(3) Time to complete the task and accuracy of performance. Turn to Page 22.
(4) Probability of success and performance time. Turn to Page 42.

From Page 9

(1) This is the definition of a task, not a task inventory. Return to Page 4.

From Page 16

(2) Correct. Human factors test and evaluations are used to determine whether (and to what level or standards) each trained individual can perform in the specified sequence all the performance tasks assigned to him in a system.

Let's try another question. Which of the following answers best explains how the trained individual's performance could be influenced?

(1) Population stereotypes were incorporated in control/display design. Turn to Page 10.
(2) Equipment configurations result in good work space design. Turn to Page 47.
(3) Performance by other personnel can influence the individual in the system. Turn to Page 3.
(4) All of these are factors which can affect performance. Turn to Page 73.

From Page 24

(1) This sounds good, but there is not always a premium on longevity, particularly in areas of rapid technological change. Return to Page 24.

From Page 29

(3) The 'time slice' approach is a valid first step toward identifying total manpower requirements, but it does not identify all manpower requirements. Return to Page 29.

From Page 52

(2) Yes indeed, but there are other than engineering payoffs from fabricating a mock-up. Defining these payoffs is a big step toward determining how sophisticated the mock-up should be. Return to Page 52.

From Page 48

(3) We're afraid you've been too hasty in your choice. It's true that producing photographic recordings might be an important performance requirement, but there are other equally viable answers. Return to Page 48.

From Page 46

(1) Close, but no cigar. There are numerous methods to use in conducting a task analysis, but the lack of a standard definition of task analysis isn't the most serious problem. First, you have to know what a task is in order to analyze it. Try again on Page 46.

HUMAN FACTORS ENGINEERING

LESSON 22: SYSTEMS ANALYSIS, OR THE BIG PICTURE

It Will ... Lesson 22 Will

means

Welcome to the wide world of systems analysis. This lesson is a foundation for much of the information which follows, so settle into your chair and prepare to learn about the 'big picture' called 'systems analysis.' In this lesson we'll define exactly what ~~we mean by~~ systems analysis and show ~~you~~ why a knowledge of it is so important to ~~you as~~ a human factors specialist. You'll also ~~be~~ introduced ~~to~~ some of the more common techniques used when conducting a systems analysis. In addition, some of the road blocks ~~you~~ that can be expected to encounter will be presented along with ways to avoid them. But before we get all 'wrapped up' in discussions of this sort, let's check in on I. M. Eager and see how 'eager' he is to apply the knowledge of a human factors specialist.

I. M. Eager, having discovered the hard way that there are many factors which must be considered when designing equipment and machinery for humans, had decided to turn over a new leaf. He wished to break from his 'trial-and-error' procedure, and concentrate on a completely systematic evaluation of the system he was designing. Professor Ed U. Kator had decided that the best way to introduce Human Factors Engineering to Eager and his fellow students was to present a detailed overview of systems analysis theory and practice.

The purposes of systems analysis can be neatly packaged into five general areas:

1) Scheduling
2) Identifying limiting factors
3) Establishing system performance criteria
4) Identifying and explaining various design options
5) Evaluating systems.

The following paragraphs will explain these purposes and present some examples.

When developing a complex system such as a large cargo jet, systems analysis is necessary if we are to identify properly all requirements, and if we hope to understand the logical and sequential order in which they must be accomplished. For example, before we decide on engine size, we need to know how heavy the aircraft will be. A proper systems analysis will help us schedule various phases of development.

(Go on to the next page)

Cont'd pg. 27

From Page 7

Another purpose of systems analysis is the determination of factors that potentially limit or constrain system performance. Such factors as personnel skills and abilities, environmental limitations, and cost estimates all must be dealt with in evaluating system effectiveness. To return to our example, if certain noise restrictions exist for our aircraft, the analysis should uncover this and enable us to input this information to our designers.

The third purpose of systems analysis is the establishment of performance criteria which must be met by the interrelated elements of the overall system. These criteria become standards for both design and test and evaluation. Our aircraft, for example, might have criteria such as: carry so many tons of equipment; so many people; travel at supersonic speeds; and have a crew of eight men.

Further systems analysis uses these performance criteria in identification and comparison of design options. Through comparison of expected performance with performance criteria, the human factors specialist is able to use more effectively men and machines. In our example we might analyze the option of having only four operators and some automated equipment to accomplish the functions originally assigned the other four.

Finally, performance measures of the system and its subsystems are needed to determine how a 'system' can be expected to perform under actual operating conditions, or if one 'system' is better, or more efficient.

Thus, you can see that there are a number of ways in which systems analysis can be used. When do you think systems analysis is most important?

(1) When developing new systems. Turn to Page 15.
(2) When modifying traditional systems. Turn to Page 57.
(3) When a prototype is ready for testing. Turn to Page 10.
(4) All of these listed answers. Turn to Page 2.

From Page 75

(2) Very good. Of these choices, this was the only task element. Engaging the gas pedal is a subtask and driving the truck is a function. Keep up the good work.

Now that you know the definitions and have a feel for the mission and task of a system, let's go back to the parts of the task analysis definition which we haven't addressed. Do you remember that task analysis is a process applied to a task inventory and supporting data? Sure you do! Perhaps you also know what a task inventory is. Do you?

(1) Sure, it's a set of all activities done for a particular purpose. Turn to Page 4.
(2) Sure, it's a method for classifying the levels of activities in a system. Turn to Page 12.
(3) Sure, it's a listing of all tasks performed within one job. Turn to Page 64.
(4) No, but I'm sure you're going to teach me. Turn to Page 23.

From Page 26

(3) You're jumping the gun. This answer is part of the next step (task analysis) and function analysis assists you. However, first we need to look at the results of the functional analysis as it impacts the overall system acquisition procedure. Return to Page 26.

From Page 5

(1) You're only thinking of the small picture. This is only one example of a factor which can influence performance. Think big!! Return to Page 5.

From Page 15

(2) This answer is incorrect. While presentation of alternatives and trade-off results to the user is a step in the analysis, it rarely fits as a first step in the process. Return to Page 15.

From Page 66

(1) Well, this may be true, but in this question you (or another analyst) weren't performing the job. Your concern was in asking workers about their jobs. Return to Page 66.

From Page 8

(3) If you wait until a prototype has been developed to conduct a systems analysis, you're probably in a lot of trouble. Return to Page 8.

From Page 69

(2) This is exactly right. You've learned very well.

Figure 24.2 also provides you with similar informat'on in a different format. On this worksheet, the task element is broken into its Human Factors of perception (P), judgement (J), and motor components (M). These factors are then judged as to the level of each that is involved in performing every task element. For example, the first element (unscrew three hold-down screws) is judged to have a low perceptual component, but to require a moderate amount of judgment and motor abilities. Now, why do you think judgment is required in this simple subtask?

(1) It is necessary to judge which hold-down screws to unscrew. There are probably many. Turn to Page 49.
(2) It is necessary to judge the tightness of the hold-down screws. Turn to Page 59.
(3) Judgment really isn't necessary; the analyst just didn't want to leave a blank space. Turn to Page 19.

From Page 62

(3) In the later stages of the acquisition process this will be done. However, initially, we wouldn't want to reduce the design options by imposing function allocations. Return to Page 62.

From Page 31

(2) Critical tasks are found in the task inventory, but this does not tell you how far to break those tasks down. Think about the particular purpose of any particular task analysis. Return to Page 31.

- -

From Page 41

(1) This is the same phase as one other answer. Now, in this course, have you found two answers to be equally correct? Try again on Page 41.

- -

From Page 86

(4) These are two measures used in test and evaluation to assess whether or not the human has performed according to the criteria set. Essentially, these measures can confirm whether your HFE involvement in systems analysis has been successful. You've identified the end points. To answer this question correctly, you need to focus on the front-end approach. Return to Page 86.

- -

From Page 9

(2) Close, but no cigar. This answer applies to a task taxonomy. It is used for classifying activities into categories and subcategories. Therefore, it tells you how to organize your task inventory, but it is not the inventory itself. Try again on Page 9.

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From Page 84

(1) If this were true, then task analysis would be a static, set in concrete event. Return to Page 84.

- -

From Page 86

(2) The current HFE emphasis in systems analysis is the identification of the human performance specification. You were exactly right.

Currently, the government must explain in detail what a system must do and how well the system must do it (whatever it is). That is, we must now talk about the mission of the system and what the human performance must be in order to accomplish it.

Now, that doesn't should too hard, does it? Well, this may be more difficult than you initially thought. The documents typically used by HFE specialists have been stated in equipment terms. MIL-STD-1472 and MIL-HDBK 759 are valuable guides to equipment design, but they really don't give you performance data. Do they? ... No.

As we said, the first step in developing human performance specifications is to identify the purpose of mission of the system. I. M. Eager really never established the purpose of his super helicopter, he just wanted it to be super.

The purpose of a system almost automatically gives you the criteria against which to judge the system. If Eager's chopper is to be able to go from earth to the moon and back, then 'fly from earth to the moon' is its mission. Originally, ol' Eager didn't have a proper mission statement. Having a chopper which is 'super' isn't a statement of mission. Having interstellar capabilities isn't a mission statement either. To be proper, however, the purpose of a system (the mission) must be judged against two criteria: usability and completeness.

Usability can be determined by asking:

(1) Is this mission one ultimate, final purpose of this system? For example, if the ultimate purpose of Eager's chopper was to fly to the moon, then stating one mission of the chopper as supersonic speed flight is an ultimate purpose in itself. There was, of course, more intended for the chopper than just supersonic speed.

(2) Is this mission performed by one defined system, or must it be performed by several systems? For example, if Eager had stated that his chopper had the mission of maintaining outer space defenses, he would not be correct in his statement. It requires more than one helicopter or one type of helicopter to defend outer space. So far, however, Eager has been correct, 'fly to the moon' is the overall mission and supersonic speed attainment a mission in itself, which can be performed by that system (helicopter).

(Go on to the next page)

From Page 13

(3) Can we directly measure the performance of the mission? In this case, surely we can.

These three questions must all be given a 'yes' answer if your mission statement is to be considered usable. The final criterion for a system's mission statement is its completeness. All the unitary missions which must be performed should be included in the formal mission statement for the system. For example, Eager's 'fly to the moon' mission really consists of several unitary missions, such as:

(1) Supersonic speed
(2) Orbit earth
(3) Re-enter earth's gravity, and so on.

So far we have only addressed the mission statement. What is the next step in your systems analysis?

(1) Break down the mission into its activities or functions. Turn to Page 26.
(2) State the mission in the mission element needs statement (MENS). Turn to Page 19.
(3) Determine if the mission is needed. Turn to Page 39.
(4) All of these are part of the next step. Turn to Page 66.

From Page 90

(1) While functions are assigned during this phase of system development, task analysis should be applied earlier to help determine those functions. Return to Page 90.

From Page 8

(1) Well done. This was a tough one. When working with new systems there are so many unanswered questions. Unless a good systems analysis is conducted, the probability of developing a good system is quite low.

What we've done thus far is give you a general impression of the functions systems analysis serves for human factors specialists. The human factors specialist can employ systems analysis when a need arises for scheduling, identifying limiting factors, establishing system performance criteria, identifying and comparing design options, as well as overall system evaluation. In addition, systems analysis can be used in the identification and evaluation of human performance reliability. This, in turn, permits the postulation of training and personnel skills requirements.

Besides knowing when to use systems analysis, it is also helpful to be familiar with the sequential steps required. While not always done in a rigid sequence, all steps are required in one form or another. Some parts of the total system may have already been designed and tested, while time constraints may eliminate or change the sequential order in other instances. Regardless, they combine to form a model which is helpful in understanding the relationship between Human Factors Engineering and the total system engineering process. Figure 22.1 in your supplement graphically displays this model. As we continue through this lesson, as well as some following lessons (e.g., task analysis, training), it will be clearer to you how these many steps fit together if you constantly refer to this diagram.

Take a look at the diagram. Considering what you've learned thus far in this course, and thinking about the process of systems analysis in general, what would you consider the first step in systems analysis?

(1) Task analysis. Turn to Page 98.
(2) Presentation of alternatives and trade-off results to the user. Turn to Page 10.
(3) Recognition that a problem exists and that the solution may be approachable from a systems analysis perspective. Turn to Page 48.
(4) Selection and development of 'optimum' system concept. Turn to Page 100.

- -

From Page 52

(4) Not only are all the answers given true, but they will all ultimately minimize time and/or life-cycle cost.

When the evolutionary design process which may be capped by use of mock-ups is completed and the prototype is fabricated, it is the job of the human engineer to monitor the process. Often it is the case that what was a superb design on paper or plyboard requires modification to accommodate production procedures or limitations. A primary objective that the human engineer must keep in mind during this process is that factors desirable from the HFE standpoint are not to be needlessly compromised in order to facilitate production objectives.

With each stage in the acquisition cycle, the system becomes progressively firmer and more concrete. The test and evaluation process is part of every phase in the system acquisition process. Conducting test and evaluation at each phase allows for change possibilities while the system is still flexible enough to accept and accommodate those changes.

Results of the test and evaluation analysis, which is conducted during the production and deployment phase of systems acquisition, are expected to include:

(1) Confirmation of human factors research required to support training requirements and the operational concept.

(2) Validation of LOA and TDC HFE guidelines, standards, processes, and like needed documentation. The validation insures that the system objectives can be achieved by the personnel generally available to the user organization and those who have been given only the training planned.

(3) Final evaluation of training aids and devices and special training requirements.

What can we conclude is the practical thrust of the HFE effort during test and evaluation?

(1) Defining the selection criteria for determining who will be expected to operate the system. Turn to Page 100.
(2) To determine the human performance levels or standards. Turn to Page 5.
(3) Reaching a decision whether or not a man can operate or maintain the system in order to meet the objectives of its existence. Turn to Page 65.
(4) Subsequent to test and evaluation, HFE analyses seek to define what is required in order to qualify prospective operators and maintainers to meet system objectives. Turn to Page 46.

- -

From Page 61

(2) Sorry, but the question asked when anthropometry should be introduced, indicating a first consideration. This type of HFE data is important during the concept exploration phase, but it should be a consideration even earlier. When? Return to Page 61.

From Page 85

(4) This answer is an example of an overall mission statement which should be broken down into a series of unitary mission statements ... A list of required functions per mission statement ... A list of tasks per function. If you are confused about the differences among these concepts, you'd better reread the last few pages before answering this question again. Good luck. Return to Page 85.

From Page 90

(3) Waiting until a prototype exists is too late. Task analysis should be done sooner. Return to Page 90.

From Page 59

(3) This is indeed a valid statement, but there is some important preliminary activity to be completed before identifying alternatives. Return to Page 59.

- -

From Page 29

(4) Very good. A task is a combination of related activities which are done to achieve a particular purpose.

As you now know, a task is a set of activities done for a particular purpose. These activities are composed of perceptions, judgments, skills, and knowledge that go into making a response. A 'subtask,' therefore, is a set of activities which fulfill a portion of the task. Finally, a 'task element' is the smallest definable unit of behavior required in completing a task or subtask.

In order to give you some practice in thinking about the various factors involved in task analysis, let's take an example. In our example, the man-machine system is a truck and driver. The mission of the system is to deliver a message to command headquarters from point X. A function of the system would be:

(1) To drive the truck from point X to command headquarters. Turn to Page 75.
(2) To deliver the message. Turn to Page 81.
(3) To start the engine of the truck. Turn to Page 3.
(4) To change a flat tire. Turn to Page 63.

- -

From Page 61

(3) Sorry, but the question asked when anthropometry should be introduced, indicating a first consideration. This type of HFE data is important during the concept exploration phase, but it should be a consideration even earlier. When? Return to Page 61.

- -

From Page 70

(3) No. While DOD Directive 5000.1 lays out the requirements for HFE, the individual service which undertakes the procurement is primarily responsible for the details of HFE application. Return to Page 70.

From Page 14

(2) Well, we could have made this the correct answer, but aren't writing the MENS and identifying the mission just two sides of the same coin? We really are looking for the next conceptual step. Oh, if you insist, we will pat your back for being technically correct. However, just to be a nice person, why don't you try another answer so that the lesson can continue? Thanks. Return to Page 14.

From Page 11

(3) Aw, you really don't think this was the correct answer, did you? Pick another answer on Page 11.

From Page 62

(1) Well, in this case you're incorrect. This functional allocation process is one of several which contributes to the essence of HFE, but we don't want to apply it yet. Return to Page 62.

From Page 76

(4) Oops -- One of these truly is correct. Remember, you need conditions, action object, and performance standards. Return to Page 76.

From Page 74

(4) Relative weighting is a measure that is flexible to adjustment within the framework of a model. It is an important detail feature, not a requisite to design of the measurement model. Return to Page 74.

From Page 97

(2) While it is important that the measurement criteria used in any one round of trade-offs remain constant, the needs to be met and the questions to be answered will change as the system(s) become better defined. Obviously, this is not the answer. Return to Page 97.

From Page 61

(4) We hate to say this is the wrong answer, but it is. It is wrong only because the question asked for the first consideration of such HFE data. It is true that such HFE information should be considered in all phases, but when do you initially introduce it? Return to Page 61.

From Page 79

(1) There is some truth to this approach; however, not only is there the technical risk of associated systems deficiencies being keyed to HFE deficiencies, experience indicates that unless HFE issues are addressed early in the development process, they may never be resolved. Return to Page 79.

From Page 86

(1) This answer is an equipment-oriented HFE interest. We want to ensure this compatibility, but we want to state this in terms of its effect upon the human. Ask yourself questions such as, 'what must the operator do? What are the goals to be reached? How does the human function to reach these goals?'...Now try again. Return to Page 86.

From Page 59

(1) You are certainly right that dollar value is most often a key decision factor; however, other things need to be done before the way the decision is to be made is determined. Return to Page 59.

From Page 4

(3) You're right. Time and accuracy are the two characteristics which are basic to human performance. The other answers of number of type of error, user acceptability, and probability of success are all examples of additional forms for describing either performance standards or acceptance.

Time of performance is usually described in two ways: reaction time and actual performance time. Reaction time is a measure of how long it takes an individual to respond once a stimulus has been presented. For example, how long does it take to hit the shutdown control once the emergency display is activated? Performance time is typically used on task descriptions. For example, the operator will adjust dials 1, 2, and 3 to within a 10-degree error range in 1.5 minutes. The 1.5 minutes is the maximum acceptable performance time.

Errors may be specified in several ways. You can specify the total number of errors, the type of errors made, the number of errors per type.

We have been discussing performance characteristics and which of these attributes we measure. In systems analysis we need to develop performance standards for each task. That is, we want to develop the criteria for performance success. These standards or specifications are of two basic forms: probability of task success or time and error. The probability of success format combines both time and error (number and type) and is the form recommended in recent military publications.

Well, we have come full circle. The probability of success statement should be included in the mission statement. By attending to human performance specifications early in the system acquisition cycle, we human factors specialists will be able to assure that the human is capable of operating or maintaining the equipment of the acquired system. After all, that is one of the major principles of a human factors specialist.

This lesson has been detailed and you could probably do with a recap before ending. We have suggested that the systems analysis process be focused on human performance specifications. In order to develop these specifications several procedural steps were presented:

(1) Develop purpose(s) of system.
(2) Define system functions for each mission.
(3) Decompose system functions to tasks.
(4) Determine task conditions.
(5) Develop performance standards.

(Go on to the next page)

From Page 22

We recommend that you read two Human Engineering Lab (HEL) technical memoranda for a more complete understanding of these concepts. First, TM 7-80 by Kaplan and Crooks is a report dealing with the development of performance standards. Most of this lesson was developed using this memorandum. Second, TM 29-76 by Berson and Crooks is a must for understanding how to analyze human performance data. You will be using this document in subsequent lessons in this course, so you may as well be prepared by reading ahead.

So, we come to the close of Lesson 22. Take a break. Reward yourself with an ice cream cone and get ready for your next two lessons which deal with task analysis. This topic is so important that two lessons (23 and 24) will be given to you. We will keep our memory banks and storage places warm and ready to greet you then. See you in Lesson 23.

From Page 9

(4) Right you are. This may, in fact, be true and you don't know what a task inventory is. However, if you look at the other answers, you will see one which is correct and defines the words 'task' and 'inventory.'

From Page 50

(1) Correct. From this example it is possile to make decisions involving design reconsiderations, training requirements, and so on. It is a very thorough and well-summarized form.

With this piece of information we come to the end of the task analysis trail. In this lesson you learned about the task analysis process, which involved identifying tasks, subtasks, and task elements; developing SBOS; and identifying supporting skills and knowledge. In addition, you saw various types of task analysis worksheets ranging from really simplistic ones to LSAR. Task analysis is a difficult topic to understand, but since you will be constantly exposed to it in your job as a human factors specialist, we have given you two lessons on it. You next lesson will deal with trade-off analysis. Be sure to bring both your supplement and your wit with you when you return to the terminal of knowledge. In fact, it would be a good idea to look over the diagrams in your supplement before you return to the next lesson. See you!

From Page 95

(3) Right again. These four elements combined can provide a baseline alternative.

The second step of a trade-off deals with identifying the potential for development of alternative equipment designs based on manpower requirement trade-offs. Remember that these manpower requirements are themselves based on human performance requirements. The alternatives might be specified with respect to any number of selected criteria, depending on what potential trade-offs are available. Alternatives may be specified, alternative subsystems might be identified, or maintenance concepts or technology might be evaluated. Each weapon system analysis can be expected to involve a different set of alternatives. It is noteworthy that overall safety and health considerations are a key consideration in developing alternatives.

During the third procedural step, each alternative would be subjected to analysis of resource requirements. This analysis would include manpower and training requirements, the procedures for measurement of training effectiveness, as well as estimates of life-cycle costs. Additionally, each alternative is analyzed in terms of its strengths and weaknesses in satisfying the overall performance requirements.

Typically, a tabular matrix is developed to summarize the chief characteristics. Understandably for complex weapon systems, the analysis of each alternative will represent an effort of some significant magnitude that would fully justify the use of any automated means attainable and would fully exercise mathematical decision theory.

In any event, however, a standardized analysis must be conducted for each alternative.

Which of the choices given below best summarizes the major analysis of the first three trade-off steps?

(1) Maximize life-cycle potential and minimize resource requirements. Turn to Page 5.
(2) Maximum system performance capability for minimum cost with minimum manpower and minimum training. Turn to Page 97.
(3) Maximize capability and minimize manpower and training allocations. Turn to Page 98.

From Page 66

(2) Very good. Often, when people are dissatisfied with their situation, they are unable or unwilling to reveal the true source of their dissatisfaction. At these times, the complaints about system effectiveness would be symptoms of an underlying problem.

In the process of breaking down the tasks into subtasks and task elements, you will be writing statements which describe those tasks, subtasks, or task elements. Those statements are called 'task statements,' even though they man refer to subtasks or task elements as well as to tasks. The task statements always contain a verb (action to be performed) along with relevant items of knowledge and objects involved in the action; for example, a simple statement such as 'read book X.' read is an action verb and book is the object. The result of your work, then, is a set of task statements. Any task statement with a verb gets you three demerits.

So far, we have focused on stage one of the task analysis. Now tell me, what is the purpose of stage one?

(1) To determine the appropriate sequence of tasks, subtasks, and task elements for performing a job. Turn to Page 63.
(2) To determine every element of every task in a job. Turn to Page 81.
(3) To develop a list of every single task which makes us a job. Turn to Page 45.
(4) To identify a job's critical tasks, subtasks, or task elements. Turn to Page 35.

From Page 89

(3) You missed a beat. While we look for the best outcomes to meet defined minimum requirements, we look to meet their needs with the least assets expended. Return to Page 89.

From Page 14

(1) Right on. Once the mission of the system has been stated, then you need to break that down into the activities which will accomplish that mission.

After the mission statement has been defined, the HFE specialist next must break down the mission into activities and functions. The purpose of function analysis is to determine how each required function can be performed in the system and to consider the various alternatives that might lead to successful completion of the mission. Regardless of the specific steps in analyzing system functions, the processes normally involved remain unchanged. First you examine each system function to determine the kinds of capabilities needed to meet the system performance requirements. In addition, you will explore possible combinations of man-equipment capabilities in terms of the trade-offs involved.

As a final result, the functions analysis process will assist you in doing which of the following?

(1) Determining mission objectives. Turn to Page 32.
(2) Determining which design approach will maximize overall system cost effectiveness. Turn to Page 62.
(3) Determining subtasks and task elements needed by the human in order to perform the required tasks. Turn to Page 9.
(4) All of these answers are correct. Turn to Page 46.

From Page 70

(2) This answer is only partially correct. Many unique, but low priced, items are afforded a much more thorough HFE treatment than might be given to, say, an adaptation of a proven system for military use. Return to Page 70.

HUMAN FACTORS ENGINEERING

Cont'd

LESSON 23: TASK ANALYSIS I

As you may recall (how could you possible forget!), I. M. Eager really was eager to learn after his rather strange dream. He was now glad to be going to his new assignment because he would learn the techniques and methods necessary for designing his perfectly super chopper. Remember, in real life Eager was interested in designing and constructing a perfect helicopter which had land, sea, and air capabilities. His dream had illustrated for him the areas with which he needed to be knowledgeable.

When he arrived at his new command, lo and behold, he met his teacher, CPT Ed U. Kator. (Strange isn't it?) Anyway, CPT Ed's first lessons were about systems acquisition and systems analysis. After these thought-provoking sessions, Eager was ready to get his feet wet, so to speak. He was eagerly anticipating the upcoming sessions on task analysis, because these sessions would not only be informative, but would allow him to do some of the things he had been learning as well. On the morning of the first day of the task analysis seminars, Eager awakened early, dressed, and rushed to class.

~~In this~~ lesson (Lesson 23) ~~you~~ will ~~learn~~ Present the history of task analysis, what its aims are, what factors go into a task analysis, and the uses of task analysis. Figure 23.1 summarizes the overall process. Because of the importance and complexity of the upcoming material, two lessons (23 and 24) are devoted to this topic. Lesson 24 will provide you with information about the task analysis process and the techniques and the various worksheets that can be used. So, without further ado, let's begin.

Task analysis has long been considered one of the most treacherous areas of Human Factors Engineering. Perhaps an example will help you to be aware of the confusion which can exist when dealing with task analysis.

Cont'd pg. 16

In 1966 the Army document called the 'Authorized Data List' (ADL) was used as a source of data item descriptions (DID). From this list government personnel could select the appropriate 'DID' to put into government contracts. The Main Battle Tank-70 Project used an item from the ADL to request a task analysis for this project. When it was delivered, however, the document was 32 inches high! Nobody in the government was able to make much use of it.

(Go on to the next page)

From Page 27

In addition to the possibility of being confusing because of such length, task analysis can be done in a variety of ways, using a variety of techniques. This, in and of itself, wouldn't necessarily cause confusion. However. until recently, there was no uniform definition as to what a task was. Well-intentioned contractors could, and did, apply task analysis methods to their own idea of a task. Often this idea wasn't what the contracting agency had in mind.

To date, this lack of agreement as to what constitutes a task has been the single most intractable problem with task analysis. In 1978, the Test and Evaluation Subgroup of the DOD HFE Technical Advisory Group was establisted. This subgroup was composed of civilian and military personnel from the Army, Navy, and Air Force.

In March 1979, this subgroup developed a scheme for classifying and organizing human behavior which was found acceptable by 80 percent of the human factors engineering community. Part of this scheme deals with the definition of a task. Currently, a new military standard is being constructed which will contain the test and evaluation subgroup's recommendations. We, having great perceptive powers, have access to all the latest information. This lesson and the next (23 and 24) will provide you with information about task analysis which was developed by this test and evaluation subgroup.

Okay, you've gotten a short recent history of developments in the field of task analysis and you've been warned that the ground is treacherous. You also know that a good deal of confusion exists about what a task really is—even among 'experts' in the field! Now you probably want to know what task analysis is (demanding, aren't you!). Well, you've come to the right place for the answer. Task analysis is an analytic process applied to a task inventory and supporting data to produce a description of some aspect of the human component in a manned system. It further provides information for design, training, test and evaluation, manning, and workload.

That's a mouthful, but remember, you asked the question. Perhaps it will help to make things clearer if we break the definition down into its parts.

(Go on to the next page)

From Page 28

(1) Task analysis is a process--a series of steps or procedures.

(2) Task analysis is done to generate information.

(3) This information consists of a set of descriptions about the human component of a manned system.

(4) The task inventory is a set of statements of the behaviors which make up a task.

(5) Task analysis is applied to a task inventory and its supporting data.

(6) The outcome of task analysis provides information for five specialty programs: design, training, test and evaluation, manning, and workload.

You know what the aim of task analysis is. Now, let's examine various facets of the job and define them. First, what the man-machine system is supposed to accomplish is the 'mission' of the system. Second, the 'functions' of the system are the broad range of activities performed by the man-machine system. Third, a combination of all the human performance requirements necessary for operation and maintenance by one individual is a definition of a 'job.' For example, the job of truck driver would include such activities as steering the vehicle, stopping the truck, and changing a tire.

Now, we have been narrowing in on our definitions: from mission, to function, to job. Next comes a definition of a task. Which of the following do you think is a definition of a task?

(1) A chore you had to do at home in order to get your allowance. Turn to Page 67.
(2) A goal of the man-machine system. Turn to Page 33.
(3) A series of perceptions about the job. Turn to Page 57.
(4) A composite of related activities which are performed for an immediate purpose. Turn to Page 18.

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From Page 79

(2) Not at all. Time doesn't stand still for the human factors engineer to 'bless' a design. Not only would this approach to HFE be unwieldly, but it has been demonstrated time and again that once a design has been settled on, it becomes doubly difficult to overcome the 'pride in authorship' of its originator. Return to Page 79.

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From Page 46

(2) Correct. The lack of a standard definition of exactly what a task is, is indeed the single most important problem in the area of task analysis. Keep up the good work.

As the last question indicated, there is, or has been in the past, no standardized definition of a task. The recent tri-service group, however, has proposed definitions for task analysis components. These definitions are contained in your supplement as Table 23.1. Figure 23.1 in your supplement graphically portrays the topic of task analysis as we've presented it so far. Look at Figure 23.1. It shows you a theoretical scheme for task analysis. On the left, you see the inputs to task analysis, the task inventory, and supporting data. In the middle is task analysis. Notice that it is shown as a process. On the right are the five purposes of task analysis which we have discussed.

Well, since task analysis can be conducted at any time, it must be time to learn about task analysis methods. In this next section you will learn about the task analysis worksheet and the various steps to use in setting up a study of tasks, subtasks, and task elements.

What you have to use for the task analysis will be a task inventory. (Any supporting data that is available is also helpful.) Critical tasks from that inventory are selected and the task analysis is applied to those critical tasks.

(Go on to the next page)

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From Page 30

There are three stages involved in a task analysis process:

(1) Identification of tasks, subtasks, and task elements.

(2) Development of specific behavioral objectives for the tasks.

(3) Identification of supporting skills and knowledge for the tasks.

In stage one, you do the actual breakdown of the tasks into subtasks and task elements. Remember, we are assuming the tasks have already been identified in the task inventory. Two questions are important in this state: (1) How far do you continue the task breakdown? (2) How do you actually accomplish the breakdown?

See if you can answer the first of these questions. How far do you continue the task breakdown?

(1) The breakdown should always continue to the task element level to insure completeness. Turn to Page 33.
(2) It depends upon the critical tasks found in the task inventory. Turn to Page 11.
(3) It depends upon the output (design, training, etc.) for which the task analysis is being conducted. Turn to Page 78.
(4) The breakdown need only be to the task level, because the inventory supplies this information. Turn to Page 42.

From Page 69

(1) The subtask was listed in Column 3. Sorry. Try again on Page 69.

From Page 52

(3) Yes, this is true, but the examples cited are not primary justification for its fabrication. Return to Page 52.

From Page 26

(1) Oh, come on. You can't be serious. Mission objectives should be dealt with long before functional analysis is ever used. Return to Page 26.

From Page 97

(3) You're half right. While the outcomes of one analysis evolve to become the baseline of the next, the general procedures remain quite constant. Return to Page 97 for another answer.

From Page 4

(1) User acceptability does contribute to successful performance. But it really isn't an attribute or characteristic of performance itself. The accuracy portion of this answer is correct, however. Try again. Return to Page 4.

From Page 29

(2) No, the goal of the man-machine system is the overall mission of the system, not the task. Return to Page 29.

From Page 31

(1) This isn't necessarily so. It may be true in the design phase of the system, but do you think it is necessary in the training phase? Try again on Page 31.

From Page 54

(2) While this is a good design consideration and may encourage positive transfer, it is not the best answer. Return to Page 54.

From Page 83

(4) Task analysis is performed to analyze human behaviors, not equipment. Return to Page 83 and try again.

From Page 96

(2) Not quite. Decision theory mathematics has been demonstrated to be effective in reaching and supporting valid conclusions. However, there is something more basic to be done than answering questions under conditions of uncertainty. Return to Page 96.

From Page 50

(2) Well, not totally. Design purposes are well served by this information, but so are other outcomes. The form provides such information as the tools and aids which need to be used. This information is important in training development. The figure also gives error rates which can be used in design, training, test and evaluation, and so on. The required answer to this question is broader than the answer you selected. Try again on Page 50.

From Page 25

(4) Correct. Congratulations!

Now, let's go on to stage two. In this stage the task statements are converted to specific behavioral objectives (SBOS). The SBO describes the action of the task (subtask or task element), the condition(s) under which the action is to be performed, and the standard(s) or criterion of performance for that action.

Here are a number of SBO examples to help you better understand the concept:

(1) Given an electric typewriter and paper (conditions), type (action) a minimum of 50 words per minute (standard 1) with no more than five errors (standard 2).

(2) Given last year's expenditures (condition 1), this year's needs (condition 2), and projected income (condition 3), prepare (action) next year's budget within 2 days (standard).

(3) Given a malfunctioning car door lock (condition 1), a maintenance manual (condition 2), tools (condition 3), and parts (condition 4), repair the lock in 1 hour (standard).

Conditions are usually easy to determine and recognize. Wherever possible, standards should be stated in quantitative terms, as shown above. Time and accuracy are the two most widely used terms. The action terms in an SBO should be aimed at the person who will perform them, not, for example, at the trainer, if training is the outcome in question. Also, the action terms always require an object. The object of the examples above were '50 wpm,' 'budget,' and 'lock,' respectively. The action part of the SBO tells you what to do to what. Which of the following is an example of an incorrect action statement?

(1) The trainee will be able to name parts of the lawn mower. Turn to Page 76.
(2) Turn on the power of the lawn mower. Turn to Page 69.
(3) Identify the problem. Turn to Page 99.
(4) Direct the formation to the designated area. Turn to Page 91.

From Page 61

(1) Very good. Developing the MENS occurs first in the system acquisition process, and, therefore, this is when such information should be introduced. Please be aware, however, that all these phases require HFE information such as anthropometric data.

It is during the concept exploration phase that an experimental prototype or breadboard prototype may be developed. An example of this kind of prototype can be found in HEL TM 29-76 on Page 58. The breadboard type of mock-up is typically constructed of cardboard, wood, or sheet metal and is meant to represent the finished product. One of its primary purposes is to evaluate system design. Operators can go through the actions and motions they will have to make when the equipment is in operational use. Changes needed in design, personnel, and training can be determined prior to expensive full-scale development.

The 'demonstration and validation phase' immediately precedes the next major decision milestone in the system acquisition process. This phase encompasses preliminary design, during which the engineering characteristics of the various alternative designs are established and delineated. The primary objective of the demonstration and validation phase is to provide justification for full-scale engineering development decisions by the Systems Acquisition Review Council (SARC). This effort encompasses such issues as logistics requirements, preliminary estimates of cost over the life-cycle of the system, and definition of the technical risks and their potential solutions.

Subsequent to approval of full-scale engineering development and prior to the next step, the Required Operational Capability (ROC) statement is promulgated for major Army systems. Navy systems development procedure labels a similar document as 'To Level Requirements' (TLR). The ROC states concisely the minimum essential operational capabilities, and technical, logistical, and cost information needed to initiate full-scale development. When the sysem is to be developed and built by a contractor, preliminary work on Requests For Proposals (RFPS) is also undertaken during the demonstration and validation phase. Contracts may be let for software engineering support, such as manpower determinations and design rationale studies. It is easy to conclude that the human factors engineer should have a key role in these activities.

(Go on to the next page)

From Page 36

Of particular interest to the human factors engineers during this phase is the development and issuance of the Training Device Requirement (TDR) (or TD Letter Requirement [TDLR] for lesser acquisitions). These documents state the operational, technical, and cost information for training device needs and provide guidance on how training needs are to be met. The human factors engineer should have a strong input to the TDR, particularly with regard to human engineering characteristics and needs. All the documents prepared so far should emphasize system effectiveness, human performance reliability, and personnel requirements. They should embody the results of previously accomplished analyses and point the way to employment of human engineering standards and practices in the development and production of the systems under development.

It is during the demonstration and validation phase that an advanced prototype or brassboard is developed. TM 29-76 presents such a brassboard on pages 93 and 94. As you can see, this is a functional mock-up which allows the operators to actually perform tasks as they would on the job. Using such prototypes, final adjustments in equipment design can be made and additional training requirements can be defined prior to awarding contracts for full-scale development. The objective of the demonstration and validation phase is met if there is sufficient confidence that the program worth and readiness warrant commitment of resources for full-scale development and constitute a basis for the award of an enforceable contract.

'Full scale engineering development' is the third phase of the acquisition process. It begins with the awarding of development and construction contracts and ends with the acceptance of a prototype of the system being developed. During this phase the system design progresses from approved detailed contract design specifications through detailed design drawings requisite to production of mock-ups (where required) and prototype systems. Activity in this phase is not complete until appropriate solutions to the problems associated with the system (including such issues as logistics support, production, maintenance, and facilities) are obtained.

(Go on to the next page)

From Page 37

'Production and deployment' is the final major phase in DOD system acquisition. During this phase the system is manufactured, the initial required personnel training is completed, provisions for logistic support are finalized, and the entire system is tested and subsequently made operational. Although the manager charged with the systems acquisition project continues to monitor the process after production is underway and systems are deployed, the formal weapon systems acquisition process is completed at this point.

During which of the acquisition phases is it necessary to establish the anticipated functions, capabilities, and endurance requirements of weapons systems?

(1) During the contract aware phase, which clarifies just what is expected of the manufacturer. Turn to Page 81.
(2) During the concept exploration phase, when top level specifications are defined to match top level requirements. Turn to Page 43.
(3) During the demonstration and validation phase, when engineering characteristics are defined and evaluated. Turn to Page 57.

From Page 86

(3) This is only partially correct. Information processing is only one type of human performance. In a systems analysis we wouldn't limit our findings just to this human performance. The correct answer is stated more broadly than this one. Return to Page 86.

From Page 14

(3) Now, we wouldn't be into a systems analysis if the mission weren't required. The conception of the system was predicated upon a need for that system. Try again. Return to Page 14.

From Page 84

(4) Sorry, but only one of these answers is correct. Try again on Page 84.

From Page 96

(3) You are partially right here; some programs do exist that provide input to the trade-off decisions. A large measure of the problem solution is being able to identify (in advance) the questions that need to be asked. Return to Page 96.

From Page 95

(2) Not quite. At this gross level of activity, estimated software should not be singled out from the major factors it supports. A more important item is not mentioned in this choice. Return to Page 95.

From Page 43

(1) Exactly. When we lose sight of the need for integrated efforts. Engineering decisions that are not analyzed for their human impact may become quite expensive from the standpoint of overall system effectiveness.

While Human Factors should be a primary consideration from the outset of the system acquisition process, too often the only concession to human engineering is to apply lessons learned through experience.

Following the classical pattern of industrial human engineering, the first opportunity for active participation by the Human Factors engineer is normally identified as part of the preliminary design effort in the demonstration and validation phase. This participation typically is manifested in a development Request For Proposal (RFP) which may be distributed to internal agencies responsible for systems development. More typically, requests for proposals or similar instruments are distributed within the private sector of industry in order to elicit responses in the form of a proposed technical approach which would best satisfy the government's needs. In turn, the probable response of the typical engineering-oriented firm is to establish a 'proposed team' which includes a human factors engineer or someone responsible for human engineering impacts.

As it is most commonly practiced today, the preparation of a proposal is, in effect, a preliminary design activity. Many crucial engineering design decisions are made during this activity, never to be changed again, simply because human engineering needs are not fully anticipated in the RFP development. This is typically the case when a provision of a system design is a specific parameter of the contractor's bid. Quite bluntly stated, if the human factors engineer is not permitted to provide inputs during both RFP development and technical evaluation of the bids, then total positive HFE influence on the final version of the equipment or system is likely to be greatly compromised.

In some cases, specific design decisions may be allocated to the human factors engineer. Controls/display panel design and work space layout are good examples of design responsibilities assigned directly to the Human Factors engineer. Typically, other members of the team will be tasked to work out the details of how the human factors requirements can be implemented.

(Go on to the next page)

From Page 40

In most cases of design development, the human factors engineer will function in an advisory capacity, volunteering information, or responding to direct questions which will influence the design decisions. Thus, we can look at the role of the human factors engineer in the systems acquisition/development process as being primarily that of a collector, organizer, and provider of information in a decision-making/problem-solving situation. His job is to represent the potential users in the acquisiton process.

So, you know that we need human factors specialists as team members from the very beginning of the system acquisiton process. Now, at what point in the life-cycle of a piece of equipment is the Human Factors specialist finished?

(1) After the engineering-development prototype phase. Turn to Page 12.
(2) After the production and deployment phase is completed. Turn to Page 96.
(3) Most often, after the full-scale development phase. Turn to Page 75.
(4) There is no correct answer provided. Turn to Page 79.

From Page 48

(2) While this answer is indeed an operational performance requirement, it is not necessarily the only, or best answer. Return to Page 48.

From Page 4

(4) Well, we almost hate to tell you you're incorrect. Probability of success is one form for specifying human performance standards. Time is part of another form. Time also is an attribute of performance. This question deals only with performance characteristics, not standards. Please try again. Return to Page 4.

From Page 54

(3) While this is a good design consideration and may encourage positive transfer, it is not the best answer. Return to Page 54.

From Page 31

(4) If you got all the information you needed from the inventory, you wouldn't need to conduct a task analysis, would you? Return to Page 31.

From Page 38

(2) Exactly right. The conceptual generation of what is expected of a system is recorded as its Required Operational Capability (ROC) during this phase.

Now that you have a feel for the acquisition cycle, we need to identify some of the specific human factors issues which must be explored during systems acquisition.

DOD mandates through MIL-H-46855 that human engineering shall be applied during development and acquisition of military systems, equipment, and facilities to realize an effective integration of personnel into the design of a system. This effort is undertaken in order to develop or improve upon the crew-equipment/software interface. The task analysis specifies which levels of human performance are defined during the operation, control, maintenance, and upkeep of the system. The human engineering effort includes, but is not necessarily limited to, three major interrelated areas of systems development; namely, analysis, design and development, and test and evaluation.

From what has been revealed so far, what can you conclude about which stage in acquisition the human engineering efforts should be instituted?

(1) It must be an integral part of the whole acquisition process as it evolves. Turn to Page 40.
(2) It is a parallel program that assesses effectiveness in meeting integration objectives as each phase of acquisition is completed. Turn to Page 80.
(3) Human engineering relates primarily to the 'man' side of the man/machine equation. Human Factors should not directly impact on system development. Turn to Page 75.

From Page 54

(2) That is not the correct answer. One task inventory can be used for more than one purpose. Turn again to Page 54 and select another answer.

From Page 83

(1) Right on. If we had said 'how the person performs with the equipment,' then these answers would have been right. You're 100 percent correct; none of these answers is totally correct.

So, now you know that in test and evaluation, the idea is to determine whether or not a trained person can perform assigned tasks in the system; and if so, to what level of proficiency. Test and evaluation also is done to determine the extent to which human performance is affected by the equipment configuration and by other system personnel (if any). Finally, test and evaluation seeks to assess the effect of human performance on system performance.

To accomplish these purposes, it is necessary to know about critical tasks (tasks which, if not correctly performed, result in failure of the system's mission, equipment damage, or serious personal injury). You also need to know the performance criteria (performance standards) for those tasks. These criteria should be quantitative, such as time and error frequency or magnitude values.

The next outcome of task analysis is manning. Task analysis for manning is aimed at describing quantitative and qualitative (how many and which kind) personnel requirements information (sometimes called 'QQPRI' for short). This means that the task analysis has to identify the complexity level of tasks performed in the system, taking into account the system's equipment, operations, duties, tasks, and environments. Therefore, the task analysis for manning needs to be performed in such a way that you can determine the functions of each system component that is human, the relevant duties and tasks for those functions, along with the time, location, and frequency of those duties and tasks. This information has to be organized in terms of each person having a job in the system by skill level. It will then tell you how many people of each type, as well as the total, needed for the system. This applies to operators as well as maintainers.

Workload is next. The task analysis for workload must give information to determine the quality (type and category) of all tasks required to operate and maintain the system. The analysis also must give information to determine the precision (difficulty specialization, performance criteria), quantity, and timing characteristics of those tasks. Signal input, signal processing, and signal output information are also necessary. The point of workload is the number of tasks on a timeline: five tasks in an hour is not the same workload as five tasks in 1 minute.

(Go on to the next page)

From Page 44

Okay, here we go. I'm going to rev up my micro-circuits, capacitors, diodes, and all that kind of stuff to give you not one, but two questions!

First, if you do a task analysis for test and evaluation, will you have tested and evaluated the system when that task analysis is completed?

(1) Yes. Turn to Page 63.
(2) No. Turn to Page 54.

From Page 25

(3) That is not the correct answer. It applies to a task inventory, but not to stage one, which deals with the critical tasks that have been selected from the task inventory. Return to Page 25 and try again.

From Page 84

(3) Very good, you are right. Since the system changes over time, the requirements of the output categories will change also. The information they contain can be added to the inputs of task analysis, and as the life-cycle phase changes, the whole process can begin again.

Well, we have almost come to the end of the road, so to speak. This lesson primarily has been devoted to the theoretical aspects of task analysis. In Lesson 24 we will give you a bit more 'hands on experience.' So refresh yourself in the interim, but come back soon for...Lesson 24, Task Analysis II, or when is an SBO not an SBO? Between now and Lesson 24, please become more familiar with the supplemental information in Table 23.1 and the DIDS on Pages 61 through 64. See you.

HUMAN FACTORS ENGINEERING

LESSON 24: TASK ANALYSIS II

Hi, welcome back. This ~~is~~ Lesson 24 of ~~your~~ the Human Factors Engineering Course. In this lesson, you will finish the topic of task analysis, but... you probably will never finish. Learning all there is to know about task analysis in 'real life,' so to speak.

One of the purposes of task analysis is to ensure that all the human performance requirements for a new man-machine system have been identified. This has great practical importance: if the individual needs three hands and the strength of Godzilla, we want to know this before we build the system, not after. However, to know those requirements we need to have standardized definitions for the components of task analysis.

In Lesson 23 you learned some of the history and theory behind task analysis. In that lesson, which of the following was said to be one of the biggest problems that surrounds task analysis?

(1) Lack of a uniform definition of task analysis. Turn to Page 6.
(2) Lack of a uniform definition of a task. Turn to Page 30.
(3) Lack of a uniform definition of a task inventory. Turn to Page 76.
(4) Lack of a uniform. Turn to Page 84.

- -

From Page 16

(4) Wrong. When a system is accepted, there is still provision to make changes where mandated, but manpower characteristics are supposed to be integrated into the initial design--not added afterwards. Return to Page 16.

- -

From Page 26

(4) Sorry, but you're incorrect in assuming that all of these processes are involved in function analysis. Return to Page 26.

- -

From Page 5

(2) You're only thinking of the small picture. This is only one example of a factor which can influence performance. Think big!! Return to Page 5.

From Page 75

(1) Engaging the gas pedal is a subtask. It is only one of a number of subtasks that must be performed to accomplish the task. You need to look for the smallest unit of behavior to select a task element. Return to Page 75.

From Page 66

(3) This may be true, but in the long run the obtained information will be of more value than the short production disruption. There is a more serious limitation than this. Return to Page 66.

- -

From Page 15

(3) Good show. That's just what we were looking for. You were able to figure out that the diagram starts at about 9 o'clock. Recognizing that a problem exists and can be dealt with appropriately is an important first step in the process.

Once you have recognized the problem and concluded that it is one which you can resolve (you've done this through preliminary studies and basic research), your job has just begun. As a human factors specialist, you will want to determine other aspects of the system to be analyzed, such as system requirements and constraints. System requirements are objectives that must be met and include things such as the mission or purpose of the whole system and the operational performance requirements which detail the specific goals, objectives, and standards of the system's mission. (See Figure 22.2 for an example of a system requirement block diagram.) The specific system requirements for a given system should be included in the materiel acquisition documents for that system. System constraints are limits within which the objectives must be accomplished. Constraints include cost and time limits as well as environmental and resource limits.

Now, given what we have just been talking about, if your mission objective was to 'send a space vehicle into orbit,' what would you think some of the performance requirements might be?

(1) The vehicle must be capable of sustaining a crew of three members. Turn to Page 3.
(2) The vehicle must attain a planned earth orbit at an altitude of 300 nautical miles. Turn to Page 41.
(3) The system must produce permanent scientific photographic recordings of the earth's geography. Turn to Page 6.
(4) All of these answers are examples of operational performance requirements. Turn to Page 86.

- -

From Page 11

(1) Right, very good. Most of the operations we perform require some amount of judgment. However, this type of factor is not readily measured and, often, it is not included in an analysis of basic tasks.

The command for which you are working may have a completely different type of form, but it will be built on the ideas we have discussed. At your convenience, it would be a good idea if you took a look at the forms that your particular command uses so that you will become readily familiar with them. Then, when you are required to use them, you will not have to study them while conducting a task analysis. No matter what type of form is used, it is best to keep a standardized format. In this way, it can be kept as a permanent record and can be revised as the task is altered.

Another type of worksheet is that of Figure 24.3. This subdivides each task into its subtasks and provides space for recording time and error information. This type of data sheet would be very useful when doing task analysis for test and evaluation and for determining human performance reliability. This example was taken from HEL TM 22-74. If you're interested and have time after this lesson, try to get this document and look through it. There is some valuable information in it.

A document used by the Navy for assessing how well an operator can use a system in terms of workload rather than design is called MOAT. This document, as well as others, is defined and discussed in Lesson 37 of this course. The worksheets discussed so far have required a manual method for conducting task analyses. To be sure, the human must still collect the data by using the observation techniques already discussed; however, the computer is an invaluable aid in summarizing and analyzing this data. One example of the interaction of manual and computer-assisted task analysis is LSAR.

LSAR is the acronym used for the Logistics Support Analysis Report. Two examples of LSAR data sheets are in your supplement as Figures 24.4 and 24.5. Figure 24.4 is an example of the data analysis sheet that the analyst used when doing the task analysis. It provides a description of the tasks and subtasks as they occur. For example, the first activity was the removal of the front seat retaining pins. This took 15 minutes. Figure 24.4 contains the same information as Figure 24.3, but this time the information has been coded to conform to the LSAR computer format. Eventually, we expect LSAR to be modified so that HFE task analysis information will be presented as in Figure 24.6.

(Go on to the next page)

From Page 49

Remember the outcome of task analysis? Design, training...? Well, using Figure 24.6, which of the task analysis outcomes is best served by an output such as 24.6?

(1) Figure 24.6 provides data which can be used for all outcomes. Turn to Page 23.
(2) This figure (24.6) best represents a task analysis done for design purposes. Turn to page 34.
(3) Figure 24.6 is primarily a task inventory, not a task analysis. Turn to Page 63.
(4) None of these answers represents Figure 24.6. Turn to Page 99.

From Page 69

(3) The function was listed in Column 1. Sorry. Try again on Page 69.

From Page 79

(3) Yes, the more he knows about all aspects of the environment(s) the system will be operated and maintained in, and by whom, the higher the validity of his input is likely to be. And not only that, the HFE should work in concert with others on the design team in an atmosphere of give and take where all may contribute to achieving all design objectives in an efficient manner.

Now, you will learn a little more about the development of prototypes. Remember, we discussed these earlier in the lesson and distinguished between breadboard and brassboard prototypes. Mock-ups are not evaluated as products themselves, but rather they are used as tools to evaluate equipment or systems before they are actually constructed. These mock-ups are three dimensional, full-scale models which may be either static or functional. Statis mock-ups are usually constructed to size from inexpensive materials such as cardboard or fiberglass, with all major components represented by controls, pictures, drawings, and the like. A functional mock-up, as the name implies, can operate in a quasi-functional manner. It has displays that move in response to control actions and/or to simulated outside actions.

A fundamentally important purpose of mock-ups is to verify the HPR and the personnel selection standards. This is accomplished by having operators go through motions they will perform in carrying out their duties in order to discover any potential difficulties. Mock-ups not only help in getting a 'feel' for the system, they are also potentially valuable in documenting the evolution of the design and as presentation models showing design progress. In addition, mock-ups serve as a training aid for familiarizing prospective operators. The human factors engineer can use the mock-up for observational evaluations, and use checklists and tabled values to estimate the value of alternative designs. Mock-ups may also be used for having 'operators' go through a series of preselected, representative tasks in order to determine whether the operator can perform his assigned tasks within the prescribed human performance requirements as defined by time and error standards. Additionally, functional mock-ups, by reason of their built-in capability to simulate operational characteristics, provide a laboratory setting in which to conduct Development Test I.

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From Page 51

With this background in mock-up theory, try the following question. Why should a mock-up be built if all the reasons for its existence can be accomplished on the equipment itself?

(1) To confirm that the HPR are feasible, that the personnel selection criteria are appropriate, and that the operations and maintenance training burdens are sustainable. Turn to Page 84.
(2) Mock-ups can provide a valuable, yet relatively inexpensive, opportunity to gain assurance that the system design is a good one. Turn to Page 6.
(3) The mock-up is a flexible and valuable tool that can serve to support a myriad of functions from training to public relations. Turn to Page 32.
(4) All the answers listed here are true. Turn to Page 16.

From Page 72

(4) Workload requirements are probably some of the most changing parameters. The idea is to reduce them, if possible. Try again, my friend. Return to Page 72.

From Page 64

Wait a nanosecond, we're searching.

Oh! There they are!

The following case history is from years ago when outboard motor boats were first developed. They were fun to operate even though they did not have a steering wheel. To steer the boat in those days, the operator would be at the back of the boat and work the tiller. Pulling the tiller handle to the left moved the boat's rudder so that the boat turned to the right. Most boat operators were accustomed to that arrangement, because that is all that was available at the time.

Then, someone got the idea of attaching ropes directly from the handle of the tiller assembly to a steering wheel placed at the front of the boat. The rest of the system was the same as before: turn the wheel to the left to go right. That system became instantly popular because it resembled driving a car; however, there was a serious problem with that system. It resembled driving a car in most respects, except for one important feature. The driver had to turn the steering wheel in the direction opposite to the one he or she wanted to go in. It was opposite to the car driving system and it led to collisions, because people were getting their car driving habits mixed up with boat driving.

When designing systems such as the boat's steering system and when designing training programs, it is important to consider the concept of transfer of training. This concept takes into account the past training and/or experience of the typical user. When things that an individual has learned in the past carry over and are beneficial in later situations, we say 'positive transfer' has occurred. The opposite, of course, is 'negative transfer' and that is what occurred with the example you just read.

That steering system design discussed above had an adverse effect on human performance, to say the least, until someone figured out how to arrange the ropes from the tiller to the wheel so that a right turn of the wheel would make the boat turn to the right. The person who first designed the steering wheel system failed to take important human factors into account early in the game.

(Go on to the next page)

From Page 53

So, you now know that when designing systems it is important to take into account negative and positive transfer effects. In your past lessons you learned a good deal about the proper design of displays and controls. With this information in mind, answer the following question: Which of the answers below best relates to positive and negative transfer?

(1) The use of population stereotypes in equipment design. Turn to Page 90.
(2) The use of shape coding in control design. Turn to Page 34.
(3) The use of auditory signals to relieve the overburdened visual system. Turn to Page 42.
(4) All of these are good design considerations which relate to positive and negative transfer. Turn to Page 80.

From Page 45

(2) Congratulations. 'No' is the correct answer. The task analysis would provide information to facilitate doing a first rate job on test and evaluation, but would not do the testing or evaluating itself. You also know that this same principle applies to the other four purposes of task analysis (design, training, manning, and workload), as well.

Now, can one task inventory be done for more than one analysis purpose (design, training, test and evaluation, manning, workload), or must a separate inventory be constructed?

(1) One task inventory can be used for more than one purpose. Turn to Page 84.
(2) A separate task inventory must be constructed for each purpose. Turn to Page 43.

From Page 59

(2) You've got it. The first step is to determine whether or not the item under consideration is a candidate for trade-off analysis.

It is not always possible to achieve an optimum balance among possible criteria for measuring the effectiveness of a given design of man-machine system; quite often some give and take must be accepted. Typically, some desirable features of one design may have to be sacrificed, at least in part, to meet more pressing systems requirements. This is practically illustrated when the human factors considerations (which might have made the design 'optimal') are traded off to reduce acquisition cost. You, therefore, need to know how a trade-off is conducted, so that you can defend yourself when your program is a candidate for being traded off.

There are two families of trade-offs that may be used in the context of this lesson.

The first trade-off grouping encompasses what is called configuration or geometry of design (this includes what Naval architects call system arrangement). Take the complex design of a warship, for example. The spatial relationships between components and the features which allow the ship to meet military readiness requirements can become quite costly in terms of overall utilization of available resources. For example, increasing radar antenna height to clear surrounding obstructions raises the ship's center of gravity and, therefore, makes it less stable in the water. While the requirement to have unenclosed space around the antenna may be of vital concern, unfortunately, all of the antenna must have ship under it, and ships are expensive to build.

Another shipboard example can be found in the mounting of weapons. Reducing the size and number of sectors where weapons fire is blocked typically increases the ship's length. There is usually a price to be paid in size, weight, or dollars in return for broad margins of safety in operation. In addition to these trade-offs which relate to mission performance, many internal arrangements, although desirable from a human engineering standpoint, can have significant impact on warship size, weight, and cost. We are often called upon to answer questions such as, 'how much would your HF design change proposal cost, and is it worth that much?"

The second family of design trade-offs is related to manpower allocations. Different operating requirements, safety margin requirements of a system, and a need to be operationally self-sufficient are examples of questions that typically result in trade-offs among qualitative and quantitative manpower alternatives. Manpower trade-off considerations can be both far reaching and sensitive. Nowhere is this sensitivity more obvious than

(Go on to the next page)

From Page 55

in the area of automation. For example, as engineering capabilities simplify the operation of equipment, the problem of personnel selection and training are reduced. On the other hand, the maintenance requirements of such systems demand technicians who have exceptional performance capabilities. Thus, the problems of selection and training are increased. Moreover, as you know, all the armed services are now relying on volunteers for their manpower. So, instead of designing a system and then going out to select people to operate it, we now need to explain to designers the kind of people we have and the skills they possess, and then insure that the human performance requirements of the design do no exceed those skill levels.

Since most trade-off issues can be broadly grouped into two families, doesn't it logically follow that design engineers should look after the hardware while human factors engineers concern themselves with manpower concerns?

(1) Design engineers must always aim their efforts toward complementing man's needs so that he can operate more efficiently. Turn to Page 77.
(2) This is essentially so, but clear communication channels must be maintained so that the manpower people can react in a timely manner. Turn to Page 83.
(3) Not at all. The trade-off issues are so intertwined that consideration needs to be given to all four factors (personnel, training, equipment, and human performance requirements) when making trade-off decisions. Turn to Page 71.

From Page 29

(2) No. To start with, an entire community of key players has been left out here. Return to Page 29 for another try.

From Page 38

(3) True, engineering standards are defined during the demonstration and validation phase, but first, top level specifications of the overall systems requirements have to be promulgated before they can be refined. Return to Page 38 and try again.

From Page 8

(2) When you modify a traditional system, a systems analysis is by no means out of place, but its use is more crucial elsewhere. Return to Page 8.

From Page 29

(3) A series of perceptions about the job might be a part of the task, but only a part. After all, if you perceive something and then don't respond, you probably haven't performed the task. Try again on Page 29.

From Page 83

(5) Sorry, but we fooled you. All of these answers are correct only if you are referring to the human, not the equipment. Return to Page 83.

Lesson 25 Will Discuss

HUMAN FACTORS ENGINEERING

LESSON 25: AFFORDABILITY, OR ARE WE MAKING THE RIGHT CHOICE?

Let's move right along; it's almost time for class to begin. Today Dr. Ed U. Kator is going to talk about some of the practical issues that arise in cost/benefit trade-offs.

This lesson should provide some insights into an important area where system and task analysis skills are typically put to use.

Every day each of us is involved in making cost/benefit trade-off decisions. In the same regard, we also identify the criteria by which these decisions are made. For instance, when you got dressed this morning, did you look in your closet and choose the clothing you are wearing? Was that selection based on a requirement to dress for a conference, your mood, or the fact that you could only find a clean shirt that went with blue or grey? Regardless, you recognized a need to meet a certain standard of dress; you established a criterion for making your selection (style, color, availability); and conducted an elementary trade-off analysis based on these needs, criteria, and alternatives. All right, we realize LT Eager just had a choice of whether or not to put on a fresh uniform. But how about lunch yesterday? Did you stop by for a burger or a plate lunch at a restaurant? Did you bring in a sandwich or, simply, did you not have time enough to eat? Regardless of the criteria-time, availability, convenience, or cost--the point has been made that we are all experienced in trade-off analyses.

In order to meet the performance and cost requirements of the military, various trade-off analyses must be conducted throughout the system acquisition cycle. The initial and most dramatic trade-off analyses are conducted during the concept exploration phase of preliminary design. You recall from your study of the acquisition process, that an objective of the concept exploration phase is to satisfy the need for a system in terms of mission element needs (MENS). Eventually, operational needs are defined in terms of system parameters, such as capability, capacity, and endurance, which are called the required operational capability (ROC) or top level requirements (TLR). Trade-off analysis is a key portion of the processes involved in deciding which subsystems and components will comprise a system. For example, trade-off analysis will help provide answers to questions such as, 'what fire control system best meets the support criteria developed for a new version of a new antiarmor missile system?'

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From Page 58

At this point, what can you conclude about how a trade-off analysis should be undertaken?

(1) The first step is to put a dollar value on all the potential alternatives. Turn to Page 21.
(2) The first step in trade-off analysis is to establish why an analysis should be conducted. Turn to Page 55.
(3) The first step is to list all the functions assigned to man and/or to machines. Turn to Page 17.

From Page 69

(4) Good show, but wrong. However, we're glad to see you've kept your sense of humor. Return to Page 69 and try again.

From Page 11

(2) It isn't really necessary to judge the tightness of the screws. Go back to Page 11 and try again.

From Page 70

(1) That's right, the actual application of HFE reflects the status of the system or equipment to be procured and its intended use.

Let us turn now to an outline description of the weapon system acquisition process.

The first step in any acquisition requiring operational development is establishing the need for a new system. While present system obsolescence may be considered to be important, the fact that there is a specific capability need which cannot be satisfactorily met by current systems or equipment is at the heart of justifying a new acquisition. The need and justification for acquisition must be fully developed in a 'Mission Element Need Statement' (MENS) by the requirement originating activity. Let us assume that the acquisition decision has been justified and subsequently approved by the appropriate level of the System Acquisition Review Council (SARC). In so doing, the proposed system has proceeded from milestone zero into the acquisition process.

After the need for a new system has been established, there are four major phases in the military weapons system acquisition process. The first three phases are punctuated by a review and approval process.

The 'concept exploration phase' represents the initial effort toward defining the need for a particular system. Its purpose is to establish in broad terms the performance, cost, and schedule requirements of the system. Several processes occur during the concept exploration phase. First, in the materiel concept investigation, the human factors specialist conducts studies to determine the upper and lower limits of acceptable human performance, determines the extent of the manpower-equipment interface, and identifies human performance requirements. Of course, if the system being developed is new, these human factors studies may be primarily conceptual in nature. That is, data used in these studies will have come from other systems which are similar to this one. From those data, determinations such as the human limitations and requirements can be estimated.

Following the materiel concept investigation, the acquisition team establishes an overall conceptual picture of what the system will be in terms of function, size, endurance, and capabilities which, in total, comprise the preliminary top level requirements expected of the system. This subphase also develops a conceptual baseline and a firm basis from which to initiate preliminary system design.

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From Page 60

The outcome of the concept exploration phase includes a Letter of Agreement (LOA), a document in which the system user and the material developer outline the basic agreements for further investigation. The LOA documentation specifies the agency responsible for conducting and reviewing the HFE analysis. Specific objectives of the analysis include identification of operator and maintainer tasks to develop training requirements; identification of human factors research required to support the training requirement and operating concept; and identification of HFE guideline standards, processes, and the like necessary to ensure that operational performance objectives can be met by available personnel. The LOA further identifies training devices and aids and special training requirements. Similar meterial is documented in the Letter Requirement (LR), which is an abbreviated version of the LOA used for acquisition of low-cost items.

The Outline Acquisition Plan (OAP) is a second joint document developed in conjunction with the LOA. It includes a plan for management of the Research, Development, Test and Evaluation (RDT&E) effort needed to achieve the materiel objectives of the LOA. In addition, the OAP contains plans for personnel and training requirements and for logistics support.

So, the concept exploration phase of systems acquisition is an involved process. In your previous 20 lessons you learned about the human in terms of anthropometry, visual capabilities, and so on. At what point in the system acquisition process should information such as anthropometric requirements be introduced?

(1) When preparing the mission element need statement. Turn to Page 36.
(2) During the first part or materiel concept investigation of the concept exploration phase. Turn to Page 17.
(3) During the experimental prototype or breadboard phase. Turn to Page 18.
(4) All of these phases require knowledge of anthropometric data. Turn to Page 21.

From Page 26

(2) Very good. You're absolutely right. A focus on cost effectiveness is an important part of functional analysis.

The process of decomposing each mission into its required function is basically one of logical analysis. At this point in the systems analysis process, do we need to show which functions should be assigned to the human and which to the machine?

(1) Yes, this is the essence of HFE. Turn to Page 20.
(2) No, it is impossible to do this in the early design stages. Turn to Page 65.
(3) Of course. In this way we can determine human performance requirements. Turn to Page 11.
(4) No. If we did, we may unnecessarily constrain the system design. Turn to Page 85.

From Page 72

(3) Life-cycle cost is a key parameter in trade-off decision making, but not the baseline factor in the initial concept we have outlined. Return to Page 72.

From Page 18

(4) Sorry, this is a task of a system. Return to Page 18 and try again.

From Page 45

(1) The task analysis would not do the testing or evaluation of the system. Instead, it would generate information needed to do an effective job of test and evaluation. This principle also applies to the other four purposes of task analysis which we discussed (i.e., design, training, manning, and workload). Select another answer on Page 45.

From Page 25

(1) The appropriate sequence of tasks is important to doing the job, but it may not be important for stage one purposes. Return to Page 25.

From Page 50

(3) If you really think this is the correct answer, you haven't understood these last two lessons very well. That is okay, because they are difficult, but you need to go back over them before proceeding.

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From Page 9

(3) Right on! Any inventory lists things, and a task inventory is no different; it lists tasks. It lists all the tasks performed in a job.

A 'task taxonomy' is a standard system for classifying the activities of a system by the level of detail of activities required. The task taxonomy organization is one that goes from a large amount of detail to a small amount of detail. In order of decreasing detail those levels are job, duty, task, subtask, and task element. So, you can see that using a task taxonomy (what we call the organization scheme) to develop the task inventory helps us examine a large set of tasks in a meaningful and orderly manner. A summary of these important definitions is provided in your supplement as Table 23.1

The definition of task analysis also uses the term 'supporting data.' Supporting data is any information which is relevant to the task analysis, but which is not found in the task inventory. For example, worker opinions and comments are relevant pieces of information. Suppose you were assigned the job of conducting a task analysis for a job which was sweaty and dirty. After determining the behavior involved, you are told by several workers that the dress code requirement will not allow ease of movement and is, therefore, hampering performance and worker satisfaction. This type of information is, indeed, important in your analysis of this particular job. Another example of supporting data is the climate (humidity and temperature) in which the tasks have to be performed.

Now that we've covered most of the terms found in the definition of task analysis, let's define it again to see how it appears together now. Task analysis is an analytic process applied to a task inventory and supporting data to produce a description of some aspect of the human component in a manned system, and to provide information for system design, training, test and evaluation, manning, and workload. There you have it.

We know that we still have not covered fully the entire definition. We haven't dealt with the second part that involves task analysis to produce information for system design, training, test and evaluation, manning, and workload. You see, this part of the definition of task analysis explains its uses. And that is the very next section of this lesson.

Before continuing, let us dip into our memory banks for two short case histories about how design affects human performance and system output.

(Turn to Page 53)

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From Page 16

(3) No, this question should have been resolved before the system was accepted. Return to Page 16.

From Page 62

(2) Right answer, wrong reason. It isn't impossible to allocate functions to both the human and the machine, but in the earliest design stages we would severely reduce the design options if this were done. Return to Page 62.

From Page 85

(2) Isn't this an example of a function required of the system (chopper)? Wouldn't there be a number of tasks to be performed in order to accomplish this function? Try again please. Return to Page 85.

From Page 90

(4) Phase four is way too late in system development. But, unfortunately, this is often when task analysis is conducted. Return to Page 90.

From Page 78

(1) Very good. While this procedure can give you valuable information, it is only possible to use it if you yourself can perform the job. This procedure may be fine to use if the job in question is that of truck driver, but what if you're analyzing an astronaut's job? Going into space, are you?

Worker opinions are also useful sources of information; after all, who knows the job and its tasks better than the person who performs them. Nevertheless, the opinions of the job performer do have limitations. First, the worker who has been operating the equipment for a long time may have become adapted to its shortcomings, and thus, no longer sees them. We've all had experience with this phenomenon, haven't we? Next, the worker may be so used to the way the system works that he is unable to think of ways to improve it.

Okay, which of the following is another limitation of worker opinions?

(1) The workers may resent an analyst who tries to perform their jobs. Turn to Page 10.
(2) The individual's complaints about the system may be expressions of his own discontent, and they may not have any relationship to the equipment itself. Turn to Page 25.
(3) The analyst will disrupt team performance while gathering the task analysis data. Turn to Page 47.
(4) All of these. Turn to Page 67.

From Page 14

(4) The next step just focuses on one of these selections. Remember, we said logical thinking is required. Try placing things in a time framework. First, someone determined that the system was needed. Then, its mission was defined. Now we need to know ...? Return to Page 14.

From Page 29

(1) Very good, but incorrect. We bet your task was taking out the trash, wasn't it? Return to Page 29.

From Page 78

(2) This could be a disadvantage, but if you can perform the job in question, you could still get the task analysis data needed. This answer may be more related to productivity of the other workers than it is to gathering task analysis information. Return to Page 78.

From Page 66

(4) One of these answers doesn't apply at all. Of the two remaining, one is a more serious limitation than the other and, therefore, is the best answer. Try again on Page 66.

From Page 76

(3) Exactly. You are correct. We congratulate you. This SBO contains the conditions of performance, the action required, and the standard against which to judge successful performance. Good show.

In stage three, you identify the skills and knowledge relevant to each SBO. Although this stage is sometimes identified as if it were separate in time from the other two stages, in practice this need not be. It is often possible to gather and arrange the data for this stage while completing stages one or two.

One key to developing supporting skills and knowledge is to examine action verbs for the task (subtask or task element) statements of stage one, or the SBO statements of stage two. This is because a good action verb will identify the type of learning involved, such as recall, recognition, or psychomotor performance. Here are a few examples: list, recite, match, remove, lift.

A second key to identifying skills and knowledge is to review available literature and documentation (e.g., supporting data) about the job being analyzed. Supporting items may include terms, symbols, basic concepts, location of objects, nomenclature, procedures (e.g., how to read a gas meter) or items of information (e.g., about 10 percent of the population anywhere in the world, civilized or primitive, is left-handed). Examples of skills can include such activities as typing, driving a car, using a voltameter, riding a horse, waterskiing, or tying your shoes. When identifying skills, you also need to identify the skill level or standard required. For example, the number of words per minute required for a typing skill.

Now that we have covered the three stages of task analysis, let's turn to the mechanics of completing it. One of the ways to document your findings from a task analysis, as well as providing you with an organization for performing the task analysis, is the worksheet that you use.

The task analysis worksheet should be constructed so that the task can be broken down into its elements. Two examples of a task analysis worksheet are provided in your supplement as Figures 24.1 and 24.2.

(Go on to the next page)

From Page 68

Figure 24.1 is a type of worksheet which provides information about the stimulus which indicates that an action is required (Column 4). It also indicates what the required action is (Column 5) and the feedback which is given, so the operator knows whether or not his action has been correct or incorrect (Column 6).

In this example, Column 5 represents what we have referred to as:

(1) Subtask. Turn to Page 31.
(2) Task element. Turn to Page 11.
(3) Job function. Turn to Page 50.
(4) I. M. Eager. Turn to Page 59.

From Page 35

(2) This is a good example of an action statement. Sorry. Return to Page 35.

From Page 2

(2) Yes, and when you think about the variety of items and systems to be acquired and applied to different uses by different users, the required procedures seem endless. So, too, are the human factors to be considered.

Each military service has its own detailed procedures for applying design and testing of HFE to new procurements. When one service acts to develop and procure materiel or a system needed by all to satisfy a Joint Service Operational Requirement (JSOR), HFE procedures applied may well be the total of all the unique service needs.

The broadest governmental procurement policy is expressed in Circular A-109 from the Office of the Management and Budget. This document seeks to establish a common framework for all acquisition programs. It defines and highlights key decisions to be made and specifies governmental levels that are responsible for making those decisions. Within the Department of Defense, DOD Directives 5000.1, 5000.2, and 5000.3 give guidance of implementing A-109. Directive 5000.1 provides policy for acquisition of major systems which exceed $75 million for research and $300 million for procurement. Its main objectives are to integrate support, manpower, and other concerns into the acquisition process. DOD Directive 5000.2 supplements 5000.1 by providing policies and procedures for the system acquisition process.

Of course, once you begin the acquisition process, you also begin the list and evaluation process as well. DOD Directive 5000.3 provides guidance in this area. Test and evaluation is so important that we have included an entire lesson (Lesson 37) devoted to this topic. Briefly, however, test and evaluation is conducted to assess and reduce risks and to estimate the effectiveness and suitability of the developing system.

Can we assume that HFE is uniformly applied to all military acquisitions?

(1) No, while some items naturally satisfy HFE needs, others will require expensive human engineering to satisfy human factors needs. Turn to Page 60.
(2) No, the HFE effort is directly proportional to the expected cost of the acquisition. Turn to Page 26.
(3) Yes, DOD Directive 5000.1 establishes HFE checklists which must be satisfied for all acquisitions. Turn to Page 19.

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From Page 56

(3) That's right. A change in one of the factors almost always causes a change in each of the other three. The idea is to meet all the performance requirements of the system with a cost-effective design which puts a minimum burden on the training base and uses the personnel skills which are most available.

One of the things we have learned in this lesson is that while the type of issues to be resolved in trade-off analysis can be grouped, each new weapon system represents a unique range of analytical issues. Trade-offs of manpower and hardware design in one system may revolve around alternative maintenance concepts, whereas in another system, the issues may relate to particular types of personnel skills required by a certain hardware design. Thus, the development methodologies capable of resolving all acquisition problems are dependent upon knowing in advance all the possible issues related to all the potential elements of the system under development.

There are no pat solution formulas to plug in, in order to achieve the best trade-off results. One objective of this lesson, therefore, is to outline procedures and approaches that present a frame work in which specific trade-off analyses may be conducted.

Figure 25.1 of your student supplement illustrates the general concept of a system trade-off analysis. As you can see, the operational requirements are already set, and they impinge on the design team. Now, the team must think about and suggest hardware configurations and personnel considerations which will meet the requirements and which will be cost-effective. The juggling of these two considerations (man and machine) is trade-off analysis.

In principle, the analysis proceeds through several stages. As previously indicated, a hardware design is postulated in response to the operational requirement. Based on this design, manpower and training requirements are determined from human performance requirements and a knowledge of personnel skills available.

At this point, the team evaluates what they have come up with. For example, someone might say, "Hey, Joe, this piece of equipment is dandy and does the job, but it will require 18 men to operate it. We only have a 6-foot space to contain the equipment and men. Now what? Do we redesign the equipment so as to allocate more functions to it and not to the men? Can we train-in the necessary behaviors so that it will take only four men to operate the machine? What are the costs of these two proposals?"

You get the idea?

(Go on to the next page)

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From Page 71

The various viable possibilities involving total capability and resource cost would be used for determining the preferred alternatives. Obviously, the selection should be based on how well prespecified criteria are satisfied. Manpower and training requirements may or may not be the deciding factor, but they will be important considerations in almost all systems acquisitions. It also has become axiomatic in the design of military systems that overall personnel safety weighs heavily in the alternative system selection process.

What major parameter is typically held constant in the demonstration and validation phase of trade-off analyses?

(1) Comparable costs in terms of man and materiel. Turn to Page 73.
(2) The system capability to meet operational requirements. Turn to Page 74.
(3) A specified level of life-cycle costing for an expected service life of the system. Turn to Page 62.
(4) Workload requirements for the selected manpower. Turn to Page 52.

From Page 5

(4) Very nice. All of these factors are, indeed, important influences of performance.

When we establish the human performance requirements, we usually use variables such as time to complete a given task, and number/type of performance errors which can be tolerated. The purpose of the tests and evaluations is to insure that these human performance requirements are met.

So, you can see that HFE requirements continue throughout the full system acquisition cycle and service life of the system.

The broad subject of the role of human factors engineers in systems acquisition has been a lot to tackle at one time. It is possible to be more detailed in aiding the human factors engineer than we have been here. To help you learn more about the system acquisition process, we recommend to you a new publication from the Human Engineering Lab, Aberdeen. This document is entitled, 'Human Factors Engineering in Research, Development, and Acquisition.' It shows you the entire acquisition process and the HFE involvement using a flow diagram approach. We suggest you secure a copy and spend a few minutes looking it over.

As the closing bell is about to ring, we want to remind you of the questions found on Page 54 of your student supplement. If you review these questions, you should have a good grasp of the framework in which we will undertake systems analysis the next time we meet. Also, the next lesson's supplemental figures should be reviewed before you tackle the text. See you soon in 'The Big Picture' (Lesson 22).

From Page 72

(1) Men and materiel are important assets, but they are usually treated as variables in a trade-off analysis. Return to Page 72.

From Page 72

(2) Right on the head. All proposed system alternatives must meet operational requirements; that is, the top level specifications for performance.

The trade-off model we have described is logical and relatively simple. It is easy to translate this model into human factors terms. For example, concerns such as accessibility, control configuration, and work space design may be assessed while maintaining minimum performance as a constant. Just how easy (or hard) it is to do trade-off analysis is directly related to the complexity of the system under consideration. While the approach may be similar, the models required for analyzing development of a new radar, for instance, would be much simpler than those required for analyzing an entire mobile command post.

It is given, then, that there cannot be one particular trade-off model or single measurement concept that allows a designer to conduct all trade-off analyses. Each round of analysis poses its unique analytical issues to be addressed and performance criteria to be met.

If no single or related family of models can be employed to meet all trade-off needs, what can we conclude to be the key element in designing a specific trade-off model?

(1) A knowledge of the human performance requirements of the proposed system. Turn to Page 94.
(2) The definition of the hardware involved must be completed first. Turn to Page 100.
(3) An economic baseline year must be identified. Turn to Page 98.
(4) The relative weights of measurement criteria must be decided. Turn to Page 20.

From Page 18

(1) Very good. The only function of this system shown above is to drive the truck.

So, now you know the mission and the function of the man-machine system. The job of the human operator is, of course, that of truck driver. In this example one of the tasks of the operator is to control the operation of the truck engine. A subtask necessary to do this would be to start the engine. A task element of this subtask would be to insert the key into its slot. Another task element would be:

(1) Engaging the gas pedal. Turn to Page 47.
(2) Turning the key to the right. Turn to Page 9.
(3) Driving the truck. Turn to Page 92.
(4) All of these are task elements. Turn to Page 99.

From Page 43

(3) Did you skip the first 20 lessons? In those lessons we noted that man cannot always physically adjust to, and should not have to operate, equipment which has not been properly human engineered. Return to Page 43.

From Page 41

(3) We hope you are kidding with this choice. After all, you just learned about an acquisition phase which follows the full-scale development phase. Try, try again on Page 41.

- -

From Page 35

(1) Correct. This statement is not a good example of a proper action statement, because it really doesn't tell the job incumbent what to do. It seems to be relating or speaking to someone else and to be stating future objectives. The proper format would have been 'name the parts of the lawn mower.'

Let's try another one. Which of the following SBOs is correct?

(1) Step on the clutch before engaging the gear shift level. Turn to Page 92.
(2) Given an operator's manual and the associated radar equipment, the trainee will familiarize himself with it. Turn to Page 89.
(3) Given a compass and a map, lead a squad of men from point 'A' as shown on that map, to point 'B' in 30 minutes, with no more than two false turns. Turn to Page 68.
(4) All of these are correct. Turn to Page 20.

- -

From Page 83

(2) Task analysis is performed to analyze human behaviors, not equipment. Return to Page 83 and try again.

- -

From Page 46

(3) The lack of a standard definition of a task inventory isn't the most pressing problem. First, you must know what a task is. Return to Page 46.

- -

From Page 78

(4) Nope, sorry. There are disadvantages and this isn't necessarily any more of an objective procedure than the other procedures. Try again on Page 78.

From Page 56

(1) This is in great measure correct in concept; however, the constraints of space, time, and especially cost tend to make this notion an academic one. Return to Page 56.

From Page 31

(3) Very good. You are correct.

The answer to the previous question depends on the output for which you are doing the task analysis. That is, which one of the task analysis data item descriptions is to be used? At an early phase, only very general information will be available about the system. Therefore, you cannot always go to a detailed level of analysis. At a much later phase, such as production and deployment, a large amount of detailed information will be available. In the latter case, you nearly always can go to a very specific level of detail.

However, remember that as soon as you have a system concept (usually toward the end of the concept exploration phase of the materiel life-cycle), you can construct a mock-up, and a careful analysis of the human performance requirements will often let you go the task element level.

The second question we spoke about dealt with how to do the sub-division or breakdown. There are at least five procedures for doing the breakdown.

(1) Perform the job.

(2) Observe the job being done by someone else.

(3) Interview those who are experts on the job content.

(4) Examine existing documents about the job.

(5) Interview supervisors of the job.

Each of these procedures has its limitations. While we won't go into a theoretical discussion of all of them here, we do, however, think it is necessary for an example or two. Let's take the first procedure.

What is a disadvantage in using the first procedure?

(1) The job often may require more expertise than you have. Turn to Page 66.
(2) Other workers may be distracted by your presence. Turn to Page 67.
(3) It is not a cost-effective procedure. Turn to Page 99.
(4) This is the most objective procedure and therefore has no serious disadvantage. Turn to Page 77.

From Page 41

(4) Right on! Even when the equipment and system are in full operation, HFE continues to apply newly developed information to the system. We come full cycle when the new developments result in a need for a new system. Very clever, keep up the good work.

The kinds of information that the human factors engineer will be expected to provide cover those subjects discussed in the first 20 lessons and more. In his role in the acquisition cycle, the human factors engineer is not limited to the issues that we have seen in these lessons. The human factors engineer would be well advised to be alert to all sources of data which might affect his conclusions and recommendations. Of particular importance are those situations which relate to the operational contexts in which the system or equipment is to be used and the engineering characteristics of the equipment itself. One can readily identify with the importance of 'user needs' in light of the series of fiascos generated by I. M. Eager as he delved into an area in which he was unencumbered by knowledge of the human engineering issues at hand.

It is more than a happy circumstance that some member of the design team is familiar with the operational environment and the problems of prospective users or operators of the system or equipment being designed. More directly, some member of the design team makes it his business to know what the user needs and expects the system to do for him and speaks for the user at the instant of making design decisions. The HFE member of the design team is a logical candidate for his duty because of training and experience.

You know the areas of knowledge that a human factors engineer must bring to the acquisition process. The question now is, what is his/her function as a systems acquisition team member?

(1) The experienced HFE will let others take the lead in blocking out system design and then point out the human factor considerations that need to be improved upon. Turn to Page 21.
(2) It is appropriate that the human factors engineer work in an atmosphere of scientific detachment. Turn to Page 30.
(3) The HFE specialist should learn as much as possible about all aspects of the environments in which the system will operate. Turn to Page 51.

From Page 43

(2) As was discussed in earlier lessons, some of the current military hardware use seems to support this statement. The human factors engineer is not supposed to get in his licks after it is too late to change things. Regretfully, it is often the case that HFE program objectives are not, indeed, being met. Return to page 43.

From Page 4

(2) Well, this answer is partially correct. There is one other major characteristic of human performance which is important and which is used in conjunction with accuracy. Go to it and try again. Return to Page 4.

From Page 54

(4) Somewhat true. These are all good design principles, but only one has an obvious relation to transfer effects. Return to Page 54.

From Page 38

(1) This is a good answer, but it doesn't fit the question. By the time contract specifications are developed, the expected performance capabilities are already recorded in some finite detail. Return to Page 38.

From Page 18

(2) Sorry, but the only function of this system shown above is to drive the truck. Try again on Page 18.

From Page 25

(2) That is not correct. In stage one you are working only with the critical tasks of a job (selected from the task inventory), not every task. Also, you may not be interested in a task element if it is at too detailed a level. Return to Page 25 and try again.

From Page 90

(2) Very good. Historically, a common error has been to omit task analysis at this phase. However, it makes sense to analyze the tasks as much as possible in the early stages of design so that errors can be avoided. It is also very important to remember to start early. But in each successive phase, the analysis should be updated (as more detailed design occurs).

That last question is an important one. It reinforces the current belief among human factors engineers that task analysis can and should be conducted early in system development. Waiting until later phases, especially the mock-up or test and evaluation phases, is too late to be cost effective. As our example points out, waiting until the system is operable can be dangerous. Early design deficiencies, especially those influencing human performance requirements in the system, may remain unnoticed until late development phases, or even until the system is operating in the field, as in the real-life case history. This means that the task analysis process needs to be applied at the earliest stage of system design and at subsequent developmental stages of the system as well. Task analysis for design will also provide a source of information for evaluators to assess the extent to which system design requirements affect human performance requirements. But, design is not the only reason for task analysis. Task analysis also discloses important information concerning the personnel skills needed and the length and cost of the training program.

Now, let's talk about task analysis for training. Task analysis for training needs to take into account four considerations:

(1) The target population.
(2) Training materials, devices, and testing that will be developed from the output of a task analysis.
(3) A definition of effective job performance of operators and maintainers which should result from training.
(4) Assessment of the training requirements of the system.

Therefore, when you perform a task analysis for training and take into account these four considerations, they will influence which data you collect, how you collect it, and how you organize it. The output of the task analysis will then be of the greatest use for application to training needs. Different methods (processes) exist for doing task analysis, and it is not a case of one method or process being best. All of them employ the same theoretical principles: break down the job into the smallest element feasible; do the breakdown in a systematic way; gather information relevant

(Go on to the next page)

From Page 82

to the task analysis purpose as the breakdown is being done; be as rigorous, quantitative, and objective as possible throughout the process. Specifically, the task analysis for training provides a description of:

(1) Each operator task required.
(2) Each maintenance task required.

The information provided in each of these descriptions should include:

(1) Task and subtask descriptions.
(2) Any HF considerations such as environmental conditions.
(3) Listing of equipment or tools required for each specific subtask.

From this type of information, you will also provide data necessary for the development of training materials, devices, and the qualitative/quantitative standards of performance.

Test and evaluation is next. But first...answer the following question. Which of the answers best describes what task analysis and test and evaluation are all about?

(1) None of these is 100 percent correct. Turn to Page 44.
(2) Task analysis done during this phase (test and evaluation) determines whether or not the hardware and software can perform the assigned tasks. Turn to Page 76.
(3) Task analysis done during the test and evaluation phase determines the proficiency levels needed by the equipment. Turn to Page 91.
(4) The test and evaluation phase seeks to assess the effect of equipment performance and system performance. Turn to Page 34.
(5) All of these answers are correct. Turn to Page 57.

From Page 56

(2) There is much truth to this statement; however, resolving the trade-off issue is a give and take (not an act-and-react) process. Return to Page 56.

From Page 54

(1) Beautiful! You got it right. One task inventory can serve several purposes.

In your supplement, Figure 23.1 summarizes what we have discussed so far. Task analysis is depicted as a process, not as a static variable. Why is this so?

(1) Because once the task analysis information is applied to the output categories the process stops. Turn to Page 12.
(2) Because the information contained in the input is used in the task analysis. Turn to Page 2.
(3) Because the output from task analysis can be used to add to task inventories or supporting data. Turn to Page 45.
(4) All of these answers are correct. Turn to Page 39.

From Page 52

(1) Yes, the mock-up can really help the human factors engineer in doing his job well, but these reasons are not the only ones. Try again. Return to Page 52.

From Page 46

(4) Lack of a uniform may be super important (if not downright embarrassing), but how does this apply to task analysis? Humorous answers are usually not correct, but they are fun. Keep plugging. Return to Page 46.

From Page 62

(4) Absolutely correct. At this point in systems analysis, we don't want to make design constraints. Eventually, the design team will determine which functions are allocated to the human and which functions are to be performed by machines. Then, we will determine the human performance requirements.

In the initial stages of systems design, we want to paint with a broad brush, so to speak. Using resources such as HFTEMAN and HEDGE will provide you with the broad categories or templates of system functions. These broad categories include such functions as:

(1) Command and control
(2) Communications
(3) Transportation

There are, of course, several other categories contained in these documents and you are not limited by just these templates. If new functions appear, of course, you include them. Oh, by the way, we know you may not be familiar with the documents just mentioned (HFTEMAN, HEDGE). Don't worry. Later in this course (Lesson 37) you will learn about them in some detail.

Let's continue with the analysis of the system. So far we have defined the mission(s) of the system and determined the functions which are required in order for the mission to be accomplished. The next step is to decompose these functions into tasks. You have to have a reasonable idea of what the human must do within the system before you can determine human performance specifications.

Task analysis is the subject material of your next two lessons. Therefore, you will only have a short section in this lesson. Generally speaking, task analysis is a systematic analysis of each function. After each function has been analyzed, you should have an enumeration of all the activities required to perform the functions.

Which of the following statements is a task required of one of Eager's helicopter crew?

(1) Plot flight path. Turn to Page 4.
(2) Orbit earth. Turn to Page 65.
(3) Fly at supersonic speeds. Turn to Page 97.
(4) Maintain interstellar peace. Turn to Page 17.

From Page 48

(4) Good show. You're absolutely right. Every one of these answers is a legitimate performance requirement of the mission.

We hope this last question helped you see that numerous operational performance requirements may be needed to satisfy a single mission objective. The purpose of analyzing system requirements and constraints is to identify the specific functions that must be performed by the system to meet those objectives. Thus, requirements analysis builds the foundation on which the human factors specialist can begin the description of system functions. Functions are the most general means whereby system requirements are met or satisfied. Function analysis is usually performed within the context of mission segments or particular objectives. Functions include such things as monitoring, controlling, or processing information. Identification, analysis, and synthesis of system functions comprise the step that translates system requirements and constraints into an organized program for implementation of design.

Before we go on (and confuse you), let's pause and review what we've said thus far. You have been given a general review of the five general purposes of systems analysis: scheduling, identifying limiting factors, establishing performance criteria, identifying and explaining various design options, and evaluating systems.

So far, our discussion has been focused on the system and not especially on the human. In the past, the HFE contribution to systems analysis has been stated in equipment terms. Previously, government HFE specialists were tasked with specifying 'design' requirements. These specifications are still important and required. Information dealing with work space design, anthropometry, and other issues you learned about in your first 20 lessons is still necessary and important if the human is to interface with the environment in the best possible way.

Currently, there is a new HFE emphasis in systems analysis. This is what OMB A-109 calls an emphasis on the front-end or initial activities of systems acquisition. The current HFE emphasis is not spoken of in terms of equipment, but rather in terms of the mission. Because of the mission orientation, HFE specialists must now identify certain specifications which are to be included in various materiel documentation. Can you determine what these specifications are?

(1) Central-display compatibility. Turn to Page 21.
(2) Human performance specifications. Turn to Page 13.
(3) Information processing requirements. Turn of Page 38.
(4) Time and error limitations. Turn to Page 12.

From Page 29

(3) You're right. The total manpower costs are predicted over the life-cycle of the system. That's hard to do in an inflationary economy.

Now, you are faced with the problem of hundreds of pieces of performance data. What do you do with it all? How do you summarize and analyze all the data? How can you make sense out of all this?

We're glad you asked, because we have an answer winging through our circuits to you right now . . . .

Each piece of performance data can be recorded and ranked with all the other pieces. In this way, you would be able to see the relative contributions of each piece of data to the required objective. This process may be called a determination model. Such a model should be designed to be adaptable to different requirements problems and may typically be divided into two parts: the executive model and the equipment model. The executive model contains both the routine which controls the computation of the requirements analysis value determinations and that routine which does 'housekeeping' chores, such as filing input data, data management, and report generation.

The equipment model contains cost equations permitting the estimation of manpower and training life-cycle costs associated with a particular weapon system. Since each system involves a unique set of issues regarding trade-off elements and system design, the specifications of the model will vary with each set of analyses. In general, however, there may be standard sets of equations for various equipment types. Therefore, the analyst would select the appropriate subset of equations to support the desired activity for a specific analysis. In instances where special concerns are being emphasized, such as the impact of the need for a particular type of supporting facility, that emphasis may be highlighted in terms of related resource costs by appropriately selecting cost equations.

Because the executive model is designed to accept numerous sets of equations formulated for different sets of equipment, it can be employed in a wide range of uses during the course of system development. The model may support trade-off analyses as they become more detailed in later stages of the system development cycle. It may, as well, assist in related analyses affecting the introduction of the new weapons systems, such as cost/benefit analysis or cost avoidance studies in support of task analysis.

Life-cycle costing models, such as the 'Army Life-Cycle Management Model,' are invariably used during the concept exploration and the demonstration and validation phases when the hardware/manpower/human factors/

(Go on to next page)

From Page 87

personnel/training trade-off studies are measured in terms of dollars. For instance, during the concept exploration phase, the model will be used to estimate aggregated manpower and resource costs which may be used as benchmarks in the conduct of trade-off analyses. As the system design becomes more specifically defined, the resource estimates may be refined to reflect greater levels of detail. Further, the model serves a monitoring function by providing a continuous record and a data source for estimating resources needed for future systems.

At the later stage of development (just before production and deployment), the cost elements should be so detailed as to permit identification of costs with specific units and installations.

A n·mber of difficulties may arise in the conduct of trade-off studies. Two major study design pitfalls are worthy of mention.

The first arises when the person designing the study restricts the range of alternatives or prejudges the merit of alternatives. For example, one trade-off might compare a costly hardware alternative with another hardware alternative, but not with any nonhardware alternatives.

The human factors engineer's knowledge and comprehension of men and machines can provide strong assistance in this regard. Under the worst of situations, an alternative may have already been chosen and alternative solutions simply investigated in order to justify the preselected alternative. This approach to alternative selection might have historically shown itself to be a good marketing technique, but it is not relevant to the production of unbiased trade-off base data.

A second problem in the conduct of trade-off analyses has to do with the credibility and confidence level of the perceived benefits in the denominator of costs/benefits ratio. At the least, it is difficult to derive and define properly clear-cut and persuasive benefits expressed in appropriate terms.

The three services are now doing a cost/benefit study of HFE technology, and we suggest that after this lesson you secure a copy of the following document. It will prove to be an invaluable aid to your understanding of the cost/benefit process. The publication is 'A Study to Determine the Methodology for Measuring the Value of Human Factors in Military System Development,' by Price, H.E., et.al., U.S. Army Research Institute Report, 1980 (TR-476).

(Go on to the next page)

From Page 88

We have used in our example a 'cost per unit' ratio as a measure of benefit. Under other circumstances, 'cost per hour of effective operation' or 'cost per adequately trained man' may be equally as valid. The point is that the relative merit of alternatives must be stated in terms which are clearly descriptive of how the system will satisfy requirements. Only when this type of quantification is made is there a full confidence that resources are being expended in the best possible way.

Since this lesson has emphasized measuring cost/benefits in terms of dollars, can we conclude that trade-off studies are just a way of finding the cheapest way to do a thing?

(1) Emphasis on dollar costs in trade-off studies is stressed simply because it is a convenient way to keep score and can be used to place values on all alternatives. Turn to Page 92.
(2) There is much truth in this conclusion. However, trade-off decisions often must weigh measures of goodness that cannot be expressed in terms of dollars. Turn to Page 91.
(3) In terms of defense, we must always select the highest of equipment capabilities. Trade-offs help us to find that best system and put a price tag on it. Turn to Page 25.

From Page 76

(2) There are at least three major reasons why this SBO is not correct. The action verb does not require actual performance and it is vague. The SBO does not have a specific object (i.e., the word 'it' could refer either to the manual or to the radar, making it ambiguous). Finally, there is no standard of performance. Return to Page 76 and try again.

From Page 54

(1) Very good. The primary reason for using population stereotypes is to ensure positive transfer effects and prevent negative transfer.

Task analysis is the one common technique used by all five areas of HFE--design, training, test and evaluation, manning, and workload. The new DIDS, approved January 1980, relate to task analysis in each HFE area.

The description and purpose sections of these new DIDS have been included in your supplement on pages 61 to 64. After you complete this lesson, we suggest that you read these pages to increase your knowledge of task analysis.

Task analysis for design of hardware and software configurations takes into account the capabilities and limitations of the target population (system operators and maintainers) and human engineering principles. Since we are discussing the design outcome of task analysis, let's step back a moment and recall the various phases in system development. These phases are:

(1) Mission area analysis--statements as to the mission of the system, stages of mission execution, and so on.

(2) Concept exploration--assigning functions to the human operator, determining the number of personnel needed.

(3) Demonstration and validation through full-scale development, how the instruments can be simplified, how configuration changes will affect the human.

(4) Production and deployment--preparation of final quantitative and qualitative personnel requirements information (QQPRI) and MOS decision, aware of contract for full-scale production.

At what point in the design phases should task analysis be applied?

(1) At Phase Two, because that is the time when functions are assigned. Turn to Page 14.
(2) At Phase One, even though it is a conceptual phase. Turn to Page 82.
(3) At Phase Three, because then there is at least a prototype. Turn to Page 17.
(4) At Phase Four, because then you have the system in existence. Turn to Page 65.

- -

From Page 89

(2) This answer is at the heart of the matter. No matter how well costs may be quantified, some considerations may escape definition; the ultimate decision still must be a human one.

In the next lesson you will be looking at a couple of the key matters that are typically identified with the demonstration and validation phase. These are reliability and maintainability. It is obvious that here there is input data for trade-off analysis. Let's get together again soon to see how these issues are viewed by human factors specialists.

- -

From Page 83

(3) Task analysis is performed to analyze human behaviors, not equipment. Return to Page 83 and try again.

- -

From Page 35

(4) This is a good example of an action statement. Try again on Page 35.

- -

From Page 75

(3) This is the function. You need to find the smallest unit of behavior in order to select a task element. Return to Page 75.

From Page 76

(1) This SBO does not contain any conditions for actions. Neither does it have a performance standard. Return to Page 76 and try again.

From Page 89

(1) There is a lot of truth to this answer. However, although dollar costs for benefits derived is at the heart of all trade-off studies, all benefits cannot be expressed in dollars. Return to Page 89.

From Page 2

(2) While some portions of the acquisition process are specifically delineated by military standards, the overall human factors need and evaluation criteria are of necessity somewhat broad. There is a better answer here. Return to Page 2.

AD-A132 560 HUMAN FACTORS ENGINEERING A SELF-PACED TEXT LESSONS 21-25(U) HUMAN ENGINEERING LAB ABERDEEN PROVING GROUND MD R BROGAN ET AL. AUG 81 2/2

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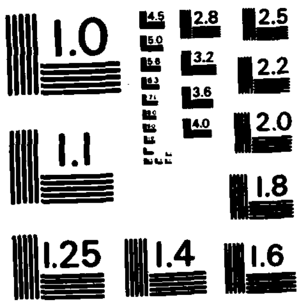

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

From Page 96

(1) You're getting ahead of the lesson, but you are right. Several specific-purpose models do exist to support trade-off analysis (and we will look at a couple).

Estimation of manpower requirements includes the numbers of uniformed and civilian personnel required to operate, maintain, and support a particular weapon system over its expected life. Included in this estimate are initial personnel allocations and operating staffs as well as the replacements necessitated by attrition or other types of manpower losses.

Training requirements encompass estimates of the number of training personnel and assets, such as simulators, school, and devices needed to provide for and participate in training. Direct and indirect training manpower requirements are a very important, yet often underestimated, subset of the manpower requirements of the total system.

In estimating these 'costs,' a very convenient unit of measure has been found to be the cost per unit. Cost estimates are initially made using a 'time slice' concept--in other words, time is frozen and estimates are made in constant value dollars without regard to personnel attrition. The cost estimate, as has been explained, should include the total number of operation, maintenance, and support personnel needed.

When the unit requirements have been determined, manpower costs can be attained using published or calculated dollar values assigned to various grades and skills. In order to reach a cost figure, the unit requirements first must be translated into military billets and civilian personnel requirements.

The important point in determining the manpower and training associated with a given alternative system is that more than the direct operation and maintenance costs are involved. Which of the following statements would you say best defines the manpower parameters of an alternative system cost?

(1) A 'time slice' of those military and civilian personnel required to operate, maintain, support, and provide training for the system when the planned number of units is operational. Turn to Page 5.
(2) The uniformed personnel operating and maintaining the system plus an appropriate share of those civilians responsible for providing support. Turn to Page 56.
(3) The numbers of uniformed and civilian personnel required to operate, maintain, and support the particular system over its expected life, including initial crews, operating staffs, and training personnel. Turn to Page 87.

From Page 74

(1) Very good. The key element in a trade-off model is knowledge of the human resource requirement. The best place to start a trade-off analysis is with what the human must do.

While there is no one selection path to answer all questions, there can be a valid general approach to conducting trade-off analyses which provides at least a systematic procedure for considering trade-offs among hardware design, personnel skill requirements, training requirements, and human performance requirements.

Trade-off analyses affecting manpower and training can be conducted effectively during the initial stages of systems development. It is during these early stages (concept exploration and demonstration and validation) that the major portion of life-cycle resources, such as training and annual operating costs, are committed. It is at this phase that the design decisions could be significantly improved as a result of the explicit identification of manpower versus hardware design trade-offs. Often, by changing the allocation of functions to human performance, significant changes can be made to personnel skill and training requirements. It is easy to conclude that the human factors specialist has a key role in this process.

There are repeated opportunities for trade-off analyses to occur during the concept exploration and demonstration and validation phases of systems development. The successive analyses are evolutionary in nature as each round of trade-offs serves to refine previous conclusions. The initial analysis, which stems from the operational requirements analysis, provides the standard or baseline for subsequent analyses, with each building on what has gone before. Through this process, significant changes in conclusions can be monitored so that changes in constraints can be recognized early in the development of the systems. Additionally, an 'audit trail' is established.

Figure 25.2 of the student supplement summarizes the four major steps included in the trade-off analysis of a typical hardware weapon system, such as a helicopter or any of its subsystems.

The first step involves defining a baseline alternative to which other helicopter designs may be compared and analyzed.

(Go on to the next page)

From Page 94

There are four elements that provide a specification for the baseline alternative. The first element is the operational requirement. Initially, the essential system characteristics are contained in the LOA (Letter of Agreement). The LOA is prepared jointly by the combat and materiel developers. Its purpose is to ensure that both developers agree on the general nature of the system.

The second element is an initial hardware concept, which will emerge based on the operational requirement. While this concept will not be a detailed specification, it does usually identify the major subsystems that comprise the weapon and, thus, provides a basis for resource requirements estimation.

Your Figure 25.2 suggests that the next occurring element is manpower/training requirements estimates. Watch out! This is one of the most serious errors in thinking. One must go through the intermediate step of specifying human performance requirements before rushing from hardware to personnel and training. Personnel and training estimates are nearly always wrong when the estimator doesn't first bother to identify the human performance requirements.

Manpower/training requirements will be used, finally, to make initial estimates of life-cycle costs for the proposed hardware design. These initial cost estimates will be broad and will undergo considerable revision during later development. Life-cycle costs will serve as one quantitative criterion for evaluating various alternatives.

To give you an idea as to the ongoing aspect of trade-off analysis step 1, let us say that from the development of the MENS to the LOA there are about three major HFE inputs required in a systems acquisition process. From the LOA to the ROC statement about 30 additional HFE inputs are made, most of which are a result of trade-off analyses. These and other HFE inputs are explained in the document entitled 'Human Factors Engineering in Research, Development and Acquisition.' You learned about this document in Lesson 21, remember?

All right, can you recall the four elements needed to complete the first step of a trade-off study?

(1) Personnel, training, equipment, and human performance requirements. Turn to Page 100.
(2) Operational requirements, hardware concepts and total resource estimates, manpower and software needs, and life-cycle cost estimates. Turn to Page 39.
(3) Operational requirements, hardward concept, resource estimates, manpower and training requirements, and life-cycle costing estimates. Turn to Page 24.

From Page 97

(1) That's right. The process is repeated as many times as it may take to incorporate all the modifications and refinements desired, with the last outcome being the starting point for the next round of analyses.

It may be concluded from earlier discussions that there are general types of computer models in use to support the more complex trade-off studies. The first model typically is the basis for determining manpower and training requirements. The second model is equipment oriented and is concerned with emphasizing how well the system requirements are met. A third model, the life-cycle model, translates input data into dollar values. In order to estimate life-cycle costs, you must first know the human performance requirements and then estimate both manpower and training requirements.

Can all of these variables that have been mentioned be managed by designing an appropriate computer-based model?

(1) Yes, but the appropriate potential issues have to be identified and weighed before the model can work. Thus far, general purpose models are modified to support specific trade-off decisions. Turn to Page 93.
(2) So much of this type of analysis is subjective, that it practically bypasses the effective use of a computer. Turn to Page 34.
(3) Yes, since the same situations have been repeated time and time again, master programs are in general use to provide the best alternatives. Turn to Page 39.

From Page 41

(2) Nope. Think a minute. Is HFE only concerned with the development and acquisition of systems? There is a better answer. Return to Page 41.

From Page 24

(2) Exactly. We are still looking for the 'biggest bang for a buck.'

The final step in the trade-off procedure is to select the preferred alternative. The analyst's choice of one of the alternatives could be the baseline alternative, or one of the others might be found to be preferable. In each case, the selected alternative now becomes the new baseline for the next round of analyses. In our helicopter acquisition example, for instance, the design selected as a result of trade-off analyses done during the concept exploration phase will become the baseline for analyses done during the demonstration and validation phase.

The procedure outlined in the preceding paragraphs works, but how well it works will depend on: How well the criteria used to evaluate. Alternatives are selected; and how clearly the relative merit of alternatives is evaluated.

Based on the foregoing, which of the following phrases best describes the overall trade-off procedure?

(1) Iterative and evolutionary. Turn to Page 96.
(2) Static and regressive. Turn to Page 20.
(3) Dynamic and evolutionary. Turn to Page 32.

From Page 85

(3) Isn't this an example of a function required of the system (chopper)? Wouldn't there be a number of tasks to be performed in order to accomplish this function? Try again, please. Return to Page 85.

From Page 2

(1) Even though many things that are in general use can be directly adapted to military use, all potential procurement must be evaluated in the light of the overall environment in which it will be used. Return to Page 2 for another answer.

From Page 15

(1) This answer is incorrect. Task analysis is certainly an integral part of a systems analysis, but it's not the first step. Return to Page 15.

From Page 74

(3) True enough, we have to keep score under the same rules, but prior to that we must decide what the game will be called. This is not the answer we are looking for. Return to Page 74.

From Page 24

(3) This is a good answer as far as it goes, but it doesn't encompass all the key issues. Return to Page 24.

From Page 75

(4) Only one of these is a task element; one is a subtask; and one is a system function. Return to Page 75.

From Page 78

(3) Huh! If your pay is a fantastic amount and you spend a good deal of time doing menial jobs, this might be a good answer. However, it isn't the best one by a long shot. Return to Page 78.

From Page 35

(3) This is a good example of an action statement. Try again on Page 35.

From Page 50

(4) If you really think this is the correct answer, you haven't understood these last two lessons very well. That is okay, because they are difficult, but you need to go back over them before proceeding. Return to Page 50.

From Page 16

(1) At this point, we are beyond developing the questions that need to be answered about operators and maintainers; rather, we are weighing results of those questions. Return to Page 16.

From Page 15

(4) Take a closer look at the model. Selection and development of system concepts come at the end of the planning stage, not the beginning. Return to Page 15.

From Page 74

(2) That's almost right; we can't start to formulate answers until the problem has been defined--but often, design of hardware can be modified to make the tasks easier for the human. So... Try again on Page 74.

From Page 95

(1) These are the four basis HFE considerations, but not the four elements needed in step 1 of the trade-off analysis. We are tempted to give you half credit for thinking HFE, however. (Well, we can't give half credit, so we'll suggest a pat on the back instead.) Now, you need to select the correct answer as it relates to Figure 25.2. Return to Page 95.

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